ΑΚΑΔΗΜΙΑ ΕΜΠΟΡΙΚΟΥ ΝΑΥΤΙΚΟΥ

Α.Ε.Ν ΜΑΚΕΔΟΝΙΑΣ

ΠΤΥΧΙΑΚΗ ΕΡΓΑΣΙΑ

ΕΠΙΒΛΕΠΩΝ ΚΑΘΗΓΗΤΗΣ: ΜΑΡΙΑ ΠΑΝΑΓΟΠΟΥΛΟΥ

ΘΕΜΑ: ROLL ON – ROLL OF SHIPS

ΤΟΥ ΣΠΟΥΔΑΣΤΗ: ΦΟΥΣΤΑΝΑΣ ΚΩΝΣΤΑΝΤΙΝΟΣ &

ΒΑΡΣΑΜΑΣ ΙΩΑΝΝΗΣ

Α.Γ.Μ: 3888 & 3861

Ημερομηνία ανάληψης της εργασίας:

Ημερομηνία παράδοσης της εργασίας:

Α/Α	*Ονοματεπώνυμο*	*Ειδικότητα*	*Αξιολόγηση*	*Υπογραφή*
1				
2				
3				
ΤΕΛΙΚΗ ΑΞΙΟΛΟΓΗΣΗ				

Ο ΔΙΕΥΘΥΝΤΗΣ ΣΧΟΛΗΣ :

Table of contents

1.Chapter 1: Introduction , Historical Data , Types of Ro-Ro Ships

2.Chapter 2: Worldwide Ro-Ro fleet, cost accounting of Ro-Ro ships

3.Chapter 3 :(Imo and safety)

We would like to offer our sincere thanks to Ms. Maria Panagopoulou for all the help and support she provided during the proccess of making this thesis.

Abstract

The purpose of this thesis is to provide insight about the evolution and usage of vessels designed to carry wheeled cargo (most commonly known as Ro-Ro ships).In the first chapter we delve into historical data about the ships' origin,usage and the technological advancements that lead to what we see today.Furthermore, we will analyse their advantages,variations, methods of securing cargo and safety parameters.

Moving forward, we have collected some data (containing a list of notable ships and information about the largest vessels) about the worldwide Ro-Ro fleet.Two important additions to that list, are the LNG fueled Ro-Ro vessels, El Coqui and Tavno.These ships, offer optimal performance and safety while setting new standards for environmentally responsible shipping.

On the final section of our thesis,we will delve into the most common critisisms to the Ro-Ro concept while detailing two of the worst disasters, the catastrophic capsizing of the passenger/car ferry Herald of Free Enterprise in March 1987 and the even more tragic loss of the Estonia in September 1994.These accidents have sparked discussions and additional safety measures to be taken, in order to avoid similar incidents from occuring again.

CHAPTER 1

(Introduction , Historical Data , Types of Ro Ro Ships)

1.1 CHRONOLOGY

At first, wheeled vehicles carried as cargo on ocean going ships were treated like any other cargo. Automobiles had their fuel tanks emptied and their batteries disconnected before being hoisted into the ship's hold, where they were chocked and secured. This process was tedious and difficult, and vehicles were subject to damage and could not be used for routine travel. An early roll-on/roll-off service was a train ferry, started in 1833 by the Monkland and Kirkintilloch Railway, which operated a wagon ferry on the Forth and Clyde Canal in Scotland.

1.1.1 Invention

The first modern train ferry was *Leviathan*, built in 1849. The Edinburgh, Leith and Newhaven Railway was formed in 1842 and the company wished to extend the East Coast Main Line further north to Dundee and Aberdeen. As bridge technology was not yet capable enough to provide adequate support for the crossing over the Firth of Forth, which was roughly five miles across, a different solution had to be found, primarily for the transport of goods, where efficiency was key.

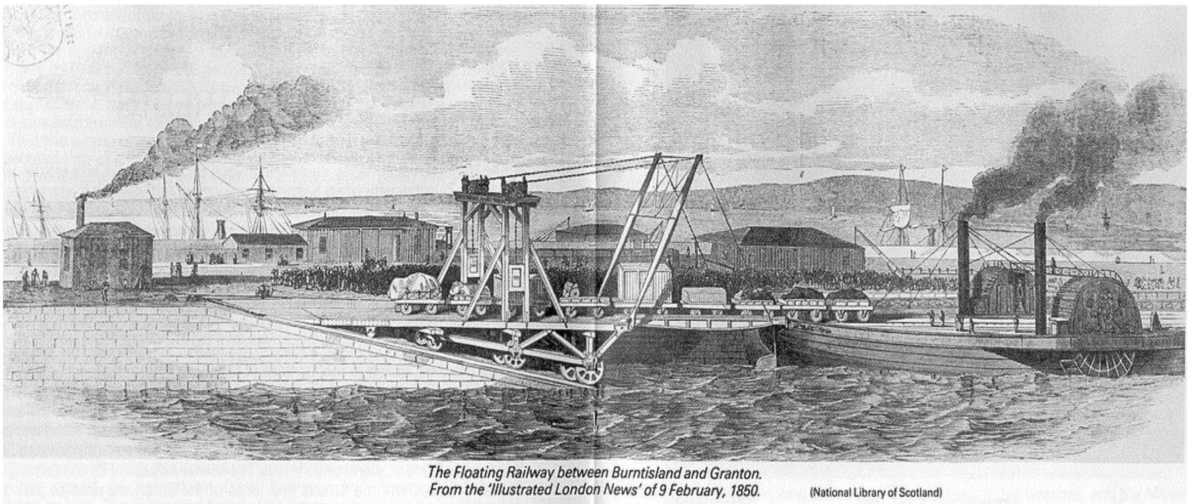
The company hired the up-and-coming civil engineer Thomas Bouch who argued for a train ferry with an efficient roll-on/roll-off mechanism to maximise the efficiency of the system. Custom-built ferries were to be built, with railway lines and matching harbour facilities at both ends to allow the rolling stock to easily drive on and off the boat. To compensate for the changing tides, adjustable ramps were positioned at the harbours and the gantry structure height was varied by moving it along the slipway. The wagons were loaded on and off with the use of stationary steam engines.

Although others had had similar ideas, it was Bouch who first put them into effect, and did so with an attention to detail (such as design of the ferry slip) which led a subsequent President of the Institution of Civil Engineers to settle any dispute over priority of invention with the observation that "there was little merit in a simple conception of this kind, compared with a work practically carried out in all its details, and brought to perfection."

(Bouch's ferry design. Note the adjustable ramp)

The company was persuaded to install this train ferry service for the transportation of goods wagons across the Firth of Forth from Burntisland in Fife to Granton. The ferry itself was built by Thomas Grainger, a partner of the firm Grainger and Miller.

The service commenced on 3 February 1850. It was called "The Floating Railway" and intended as a temporary measure until the railway could build a bridge, but this was not opened until 1890, its construction delayed in part by repercussions from the catastrophic failure of Thomas Bouch's Tay Rail Bridge.



(Floating Railway, opened in 1850 as the first roll-on roll-off train ferry in the world)

1.1.2 Expansion

Train-ferry services were used extensively during World War I. From 10 February 1918, high volumes of railway rolling stock, artillery and supplies for the Front were shipped to France from the "secret port" of Richborough, near Sandwich on the South Coast of England.

This involved three train-ferries to be built, each with four sets of railway line on the main deck to allow for up to 54 railway wagons to be shunted directly on and off the ferry. These train-ferries could also be used to transport motor vehicles along with railway rolling stock. Later that month a second train-ferry was established from the Port of Southampton on the South East Coast. In the first month of operations at Richborough, 5,000 tons were transported across the Channel, by the end of 1918 it was nearly 261,000 tons.[9]

There were many advantages of the use of train-ferries over conventional shipping in World War I. It was much easier to move the large, heavy artillery and tanks that this kind of modern warfare required using train-ferries as opposed to repeated loading and unloading of cargo. By manufacturers loading tanks, guns and other heavy items for shipping to the front directly on to railway wagons, which could be shunted on to a train-ferry in England and then shunted directly on to the French Railway Network, with direct connections to the Front Lines, many man hours of unnecessary labour were avoided.

An analysis done at the time found that to transport 1,000 tons of war material from the point of manufacture to the front by conventional means involved the use of 1,500 labourers, whereas when using train-ferries that number decreased to around 100 labourers. This was of utmost importance, as by 1918, the British Railway companies were experiencing a severe shortage of labour with hundreds of thousands of skilled and unskilled labourers away fighting at the front. The increase of heavy traffic because of the war effort meant that economies and efficiency in transport had to be made wherever possible.

After the signing of the Armistice on 11 November 1918, train ferries were used extensively for the return of material from the Front. Indeed, according to war office statistics, a greater tonnage of material was transported by train ferry from Richborough in 1919 than in 1918. As the train ferries had space for motor transport as well as railway rolling stock, thousands of lorries, motor cars and "B Type" buses used these ferries to return to England.

1.1.3 The landing ship tank

During World War II, landing ships were the first purpose-built seagoing ships enabling road vehicles to roll directly on and off. The British evacuation from Dunkirk in 1940 demonstrated to the Admiralty that the Allies needed relatively large, ocean-going ships capable of shore-to-shore delivery of tanks and other vehicles in amphibious assaults upon the continent of Europe. As an interim measure, three 4000 to 4800 GRT tankers, built to pass over the restrictive bars of Lake Maracaibo, Venezuela, were selected for conversion because of their shallow draft. Bow doors and ramps were added to these ships, which became the first tank landing ships.[10]

The first purpose-built LST design was HMS *Boxer*. It was a scaled down design from ideas penned by Churchill. To carry 13 Churchill infantry tanks, 27 vehicles and nearly 200 men (in addition to the crew) at a speed of 18 knots, it could not have the shallow draught that would have made for easy unloading. As a result, each of the three (*Boxer*, *Bruiser*, and *Thruster*) ordered in March 1941 had a very long ramp stowed behind the bow doors.

In November 1941, a small delegation from the British Admiralty arrived in the United States to pool ideas with the United States Navy's Bureau of Ships with regard to development of ships and also including the possibility of building further Boxers in the US. During this meeting, it was decided that the Bureau of Ships would design these vessels. As with the standing agreement these would be built by the US so British shipyards could concentrate on building vessels for the Royal Navy. The specification called for vessels capable of crossing the Atlantic and the original title given to them was "Atlantic Tank Landing Craft" (Atlantic (T.L.C.)). Calling a vessel 300 ft (91 m) long a "craft" was considered a misnomer and the type was re-christened "Landing Ship, Tank ", or "LST ".

(*A Canadian LST off-loads an M4 Sherman during the Allied invasion of Sicily in 1943.)*

The LST design incorporated elements of the first British LCTs from their designer, Sir Rowland Baker, who was part of the British delegation. This included sufficient buoyancy in the ships' sidewalls that they would float even with the tank deck flooded. The LST gave up the speed of HMS Boxer at only 10 knots (19 km/h; 12 mph) but had a similar load while drawing only 3 ft (0.91 m) forward when beaching. In three separate acts dated 6 February 1942, 26 May 1943, and 17 December 1943, Congress provided the authority for the construction of LSTs along with a host of other auxiliaries, destroyer escorts, and assorted landing craft. The enormous building program quickly gathered momentum. Such a high priority was assigned to the construction of LSTs that the previously laid keel of an aircraft carrier was hastily removed to make room for several LSTs to be built in her place. The keel of the first LST was laid down on 10 June 1942 at Newport News, Virginia, and the first standardized LSTs were floated out of their building dock in October. Twenty-three were in commission by the end of 1942.

1.1.4 Ro Ro'S for road vehicles

At the end of the first world war vehicles were brought back from France to Richborough Port[12] drive-on-drive-off using the train ferry. During the War British servicemen recognised the great potential of landing ships and craft. The idea was simple; if you could drive tanks, guns and lorries directly onto a ship and then drive them off at the other end directly onto a beach, then theoretically you could use the same landing craft to carry out the same operation in the civilian commercial market, providing there were reasonable port facilities. From this idea grew the worldwide roll-on/roll-off ferry industry of today. In the period between the wars Lt. Colonel Frank Bustard formed the Atlantic Steam Navigation Company, with a view to cheap transatlantic travel, this never materialised, but during the war he observed trials on Brighton Sands of an LST in 1943 when its peacetime capabilities were obvious.

In the spring of 1946 The Company approached the Admiralty with a request to purchase three of these vessels. The Admiralty were unwilling to sell, but after negotiations agreed to let the ASN have the use of three vessels on bareboat charter at a rate of £13 6s 8d per day. These vessels were LSTs 3519, 3534, and 3512. They were renamed Empire Baltic, Empire Cedric, and Empire Celtic, perpetuating the name of White Star Line ships in combination with the "Empire" ship naming of vessels in government service during the war.

On the morning of 11 September 1946 the first voyage of the Atlantic Steam Navigation Company took place when Empire Baltic sailed from Tilbury to Rotterdam with a full load of 64 vehicles for the Dutch Government. The original three LSTs were joined in 1948 by another vessel, LST 3041, renamed Empire Doric, after the ASN were able to convince commercial operators to support the new route between Preston and the Northern Ireland port of Larne. The first sailing of this new route was on 21 May 1948 by Empire Cedric. After the inaugural sailing Empire Cedric continued on the Northern Ireland service, offering initially a twice-weekly service. Empire Cedricwas the first vessel of the ASN fleet to hold a Passenger

Certificate, and was allowed to carry fifty passengers. Thus Empire Cedric became the first vessel in the world to operate as a commercial/passenger roll-on/roll-off ferry, and the ASN became the first commercial company to offer this type of service

(SS Empire Doric was one of the first commercial roro ferries. It was built as an LST and is pictured entering the harbour in Malta.)

The first RORO service crossing the English Channel began from Dover in 1953.[13] In 1954, the British Transport Commission (BTC) took over the ASN under the Labour Governments nationalization policy. In 1955 another two LSTs where chartered into the existing fleet, Empire Cymric and Empire Nordic, bringing the fleet strength to seven. The Hamburg service was terminated in 1955, and a new service was opened between Antwerp and Tilbury. The fleet of seven ships was to be split up with the usual three ships based at Tilbury and the others maintaining the Preston to Northern Ireland service.

During late 1956, the entire fleet of ASN were taken over for use in the Mediterranean during the Suez Crisis, and the Drive on/Drive off services were not re-established until January 1957. At this point ASN were made responsible for the management of twelve Admiralty LST(3)s brought out of reserve as a result of the Suez Crisis too late to see service.

1.1.5 Further developments

he first roll-on/roll-off vessel that was purpose-built to transport loaded semi trucks was Searoad of Hyannis, which began operation in 1956. While modest in capacity, it could transport three semi trailers between Hyannis in Massachusetts and Nantucket Island, even in ice conditions.

In 1957, the US military issued a contract to the Sun Shipbuilding and Dry Dock Company in Chester, Pennsylvania, for the construction of a new type of motorized vehicle carrier. The ship, USNS Comet, had a stern ramp as well as interior ramps, which allowed cars to drive directly from the dock, onto the ship, and into place. Loading and unloading was sped up dramatically. Comet also had an adjustable chocking system for locking cars onto the decks and a ventilation system to remove exhaust gases that accumulate during vehicle loading.

During the 1982 Falklands War, SS Atlantic Conveyor was requisitioned as an emergency aircraft and helicopter transport for British Hawker Siddeley Harrier STOVL fighter planes; one Harrier was kept fueled, armed, and ready to VTOL launch for emergency air protection against long range Argentine aircraft. Atlantic Conveyor was sunk by Argentine Exocet missiles after offloading the Harriers to proper aircraft carriers, but the vehicles and helicopters still aboard were destroyed.

(Atlantic Conveyor approaching the Falklands. On or about 19 May 1982.)

After the war, a concept called the shipborne containerized air-defense system (SCADS) proposed a modular system to quickly convert a large RORO into an emergency aircraft carrier with ski jump, fueling systems, radar, defensive missiles, munitions, crew quarters, and work spaces. The entire system could be installed in about 48 hours on a container ship or RORO, when needed for operations up to a month unsupplied. The system could quickly be removed and stored again when the conflict was over.The Soviets flying Yakovlev Yak-38 fighters also tested operations using the civilian RORO ships Agostinio Neto and Nikolai Cherkasov.

1.2 What are Ro-Ro ships

Ro-Ro is an acronym for Roll-on/roll-off. Roll-on/roll-off ships are vessels that are used to carry wheeled cargo.

The roll-on/roll-off ship was defined in the November 1995 amendments to Chapter II-1 of the International Convention for the Safety of Life at Sea (SOLAS), 1974 as being "a passenger ship with ro-ro cargo spaces or special category spaces"

The ro-ro ship is different from Lo-Lo (lift on-lift off) ship that uses a crane to load the cargo. The vehicles in the ship are loaded and unloaded by means of built-in ramps. Normally these ramps are made towards the stern (backside) of the ship. In some ships, they are also found on the bow side (front) as well as the sides. The vessel can be of both military and civilian types.

Ro-Ro vessels were being built in the 19th century to transport trains, too wide for the bridges, across rivers.v

An example of a Ro-Ro vessel is the Firth of Forth ferry which started operations in 1851. The rails were laid on the ship so that it could be connected to the ones on land. A train would then simply roll onto the ship and then roll off at the other end.

(Credits: hafen-hamburg.de)

There are various types of ro-ro vessels, such as ferries, cruise ferries, cargo ships, and barges. The ro-ro vessels that are exclusively used for transporting cars and trucks across oceans are known as Pure Car Carriers (PCC) and Pure Truck & Car Carriers (PCTC) respectively.

Unlike other cargos that are measured in metric tonnes, the ro-ro cargo is measured in a unit called lanes in meters (LIMs). LIM is calculated by multiplying cargo length in meters by the number of decks and by its width in lanes. The lane width will differ from vessel to vessel and there are a number of industry standards.

The largest ro-ro passenger ferry is MS Color Magic. It weighs 75,100 GT (Gross Ton). It entered the service in September 2007 for Color Line. It was built in Finland by Aker Finnyards. The ferry is 223.70 m long, 35 m wide and can carry 550 cars as well as 1270 lane meters of cargo.

The ro-ro passenger ferry with the greatest car-carrying capacity is the Ulysses. The ferry was named after a novel by James Joyce and is owned by Irish Ferries. It entered the service on 25 March 2001 and operates between Dublin and Holyhead. It weighs 50,938 GT and is 209.02 m long and 31.84 m wide. It can carry 1342 cars and 4101 lane meters of cargo.

1.2.1 Advantages of Ro-Ro ships

A ro-ro ship offers a number of advantages over traditional ships. Some of the advantages are as follows:

- For the shipper, the advantage is speed. Since cars and lorries can drive straight on to the ship at one port and then drive off at the other port within a few minutes of the ship docking, it saves a lot of time of the shipper.

- It can also integrate well with other transport development, such as containers. The use of Customs-sealed units has enabled frontiers to be crossed with the minimum of delay. Therefore, it increases the speed and efficiency of the shipper.

- The ship has also proved extremely popular with holidaymakers and private car owners. It has significantly contributed to the growth of tourism. A person can take his car from one country to another by the sea with the help of a ro-ro vessel.

1.2.2 Variations of Ro-Ro ships

Pure Car carriers(PCC) /Pure Car Truck Carriers (PCTC)

Pure Car carriers(PCC) /Pure Car Truck Carriers (PCTC)have a box-like framework, with the arrangement of ramps to load and unload the cargo. The pure car carrier is used to transport only cars whereas PCTC is used to transport all types of vehicles.

These consists of a quarter ramp in a stern, 2 ramps on both the sides, covered internal ramps and hostable decks are used to transfer the cars into multi-level decks. Vehicles drive directly into the ship and via internal ramp system to various decks.

ROPAX

ROPAX is an acronym for roll on/roll off a passenger. It is a ro-ro vessel built for freight vehicle transport with passenger accommodation. The vessels with facilities for more than 500 passengers are often referred to as cruise ferries.

(RoPax Ship)

RoLo

RoLo is an acronym for roll-on lift-off vessel. It is also a hybrid vessel type with ramps serving vehicle decks but the other cargo decks are accessible only by crane.

These vessels are capable of carrying both Vehicles and general cargo or heavy metals. Since the weight of general cargo items or the Heavy metal pieces may exceed the payload of the ramp, ship/shore cranes can be used to load and discharge the cargo directly into the hold.

ConRO

The ConRo vessel is a hybrid between a ro-ro and a container ship. This type of vessel uses the area below the decks for vehicle storage while stacking containerized freight on the top of the decks.

(ConRo Ship)

In some vessels, there are such arrangements where the vessel is divided into 2 parts, the underdeck of one side has cell guides wherein the containers can be loaded and the other side underdeck has all arrangements for carrying cars or other such vehicles. Full cargo carrying space on deck is used for carrying containers.

1.2.3 Stowage of securing of vehicles

Principal Sources of Danger

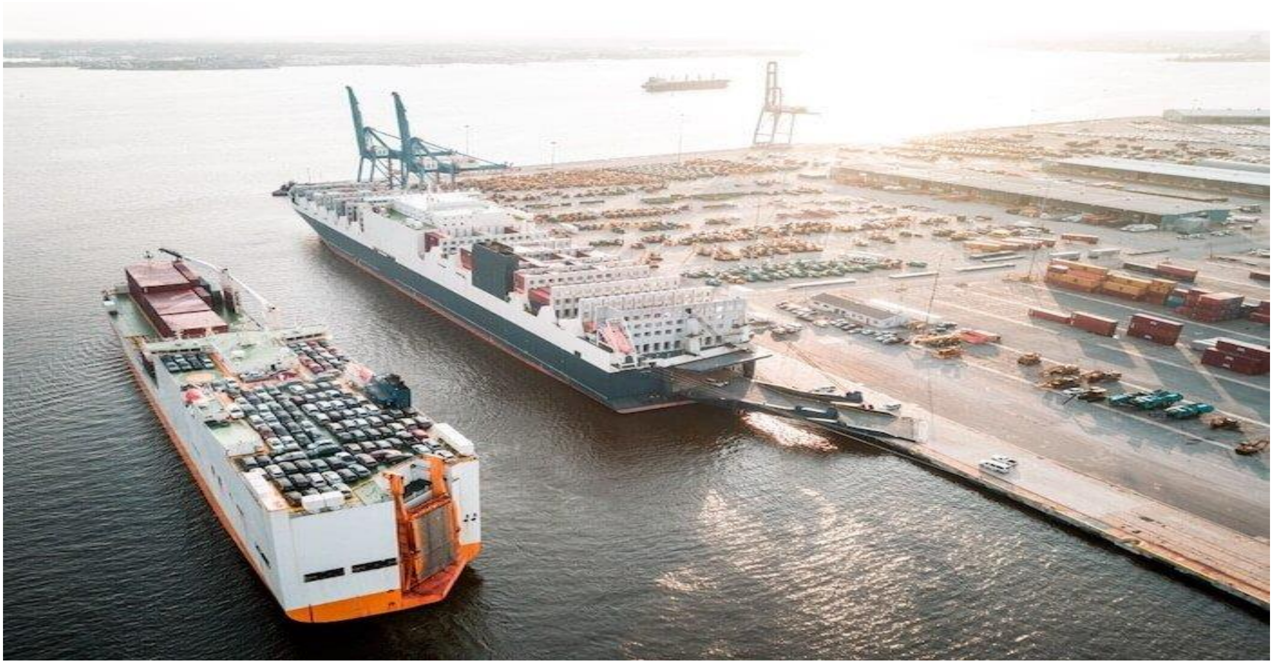
Though Ro-Ro vessel's make a very small proportion of the Merchant marine tonnage, there have been many accidents involving these, giving rise to far worse consequences. It is very important to understand the "Sources of Danger "which leads to such petrifying situations. These sources of danger don't only affect the safety of roll-on/roll-off vessels but also the passenger/crew in it.

- The unacceptable condition of the consignment constraining it to be properly lashed for Sea. Example: insufficient number and incorrect positioning of securing points, Weak securing points etc.

- The free surface effect in tank vehicles and tank containers which are slack;

- Poorly maintained ramps, lifts and bow and stern doors;
- Poorly maintained, inadequately illuminated or badly planned decks;
- Wet Decks;
- Vehicles being moved negligently on vehicle decks and ramps;
- The reversing of road vehicles on vehicle decks and ramps;
- Insufficient or incorrectly applied lashings or wrong use of Lashing equipment or of inadequate strength having regard to the mass and centre of gravity of the vehicle and the weather conditions likely to be encountered during the voyage;
- Free play in the suspension of vehicles;

The Ro-Ro's s are true workhorses of Sea. Their versatility to transport diverse cargo and short port stay show their efficiency. The cargo carrying capacity of any vessel increases the vessels earning efficiency. So, It is very important to make optimal utilisation of cargo space which has been inherently problematic with the Ro-Ro concept, in order to contrive optimal stowage plans.



Below are the few basic points we must remember while stowing cargo in Roll on-Roll Off vessels:

- Shippers' special advice or guidelines regarding handling and stowage of individual vehicles should be observed.

- Vehicles should, so far as is possible, be aligned in a fore and aft direction

- Vehicles should not be stowed across water spray fire curtains.

- Vehicles should be closely stowed athwartships so that, in the event of any failure in

- the securing arrangement's or from any other cause, the transverse movement is restricted. However, sufficient distance should be provided between vehicles to permit safe access for the crew and for passengers getting into and out of vehicles and going to and from accesses serving vehicle spaces.

- Safe means of access to securing arrangement's, safety equipment, and operational controls should be provided and properly maintained. Stairways and escape routes from spaces below the vehicle deck should be kept clear.

- Vehicles should not obstruct the operating controls of bow and stern doors, entrances to accommodation spaces, ladders, stairways, companionways or access hatches, fire fighting equipment, controls to deck scupper valves and controls to fire dampers in ventilation trunks.

- Parking brakes, where provided, of each vehicle or of each element of a combination of vehicles should be applied.

- Semi-trailers should not be supported on their landing legs during sea transport unless the landing legs are specially designed for that purpose and so marked

- Semi-trailers should not be supported on their landing legs during sea transportation unless the deck plating has adequate strength for the point loadings.

- Uncoupled semi-trailers should be supported by trestles or similar devices placed in the immediate area of the drawplates so that the connection of the fifth-wheel to the kingpin is not restricted.

- Depending on the area of operation, the predominant weather conditions and the characteristics of the ship, freight vehicles should be stowed so that the chassis is kept as static as possible by not allowing free play in the suspension. This can be done by securing the vehicle to the deck as tightly as the lashing tensioning device will permit or by jacking up the freight vehicle chassis prior to securing or, in the case of compressed air suspension systems, by first releasing the air pressure where this facility is provided.

- Since compressed air suspension systems may lose air, adequate arrangements should be made to prevent the slackening off of lashings as a result of air leakage during the voyage. Such arrangements may include the jacking up of the vehicle or the release of air from the suspension system where this facility is provided.

There are also certain difficulties faced by cargo operators in the stowage of cargo in Ro-Ro Ships:

- Cargo stowage on deck

- Various types or varieties of Cargo

- Shape of Cargo
- Securing the cargo within the unit
- The lack of transverse bulkheads
- Loading conditions
- Stability and rolling periods

Securing

Proper securing of any cargo is of utmost importance to the Safety of life at sea. The shape of a Ro-Ro is such that any condition of instability can lead to a disaster. Even according to a DNV survey, ”Shifting of Cargo” has been one of the major reason for Marine accidents involving Ro-Ro’s.

Below are some important points to consider:

- Securing operations should be completed before the ship proceeds to sea.
- Persons appointed to carry out the task of securing vehicles should be trained in the use of the equipment to be used and in the most effective methods for securing different types of vehicles.
- Persons supervising the securing of vehicles should be conversant with the contents of the Cargo Securing manual.
- Freight vehicles of more than 3.5 tonnes should be secured in all circumstances where the expected conditions for the intended voyage are such that movement of the vehicles relative to the ship could be expected. So far as is reasonably practicable the securing arrangements should be adequate to ensure that there will be no movement from any cause which will endanger the ship.

1.2.4 How safe are they?

ommercially Ro-Ro's have always been successful due to its flexibility, integration and operational speed. Despite being commercially successful. Ro-Ro's have always been criticised for its design and is also said to be one of the reasons for the disturbing accidents involving Ro-Ro's. Mainly the concerns are from the safety point of view. Some of them are listed below:

- The lack of internal bulkheads
- Cargo access door
- Stability
- Low freeboards
- Cargo stowage and securing
- Life-saving appliances
- The crew

As per IMO's circular released in January 2017, nearly 2/3rd of the lives lost at sea was from the accidents of Ro-Ro's only. This shows that the effect of Marine accidents involving Ro-Ro's has enormous consequences. Many steps were taken by IMO in order to reduce these accidents and some of them left an implacable effect on this industry too. Improving safety onboard Ro-Ro's has been one of the major topics of discussion.

The only introduction of new laws, rules or conventions doesn't change the picture. One of the studies on causes of Major accidents reflects that shift of cargo and operational faults has been the major accidents of all these accidents. These accidents were the result of improper implementation of the regulations and through Human errors.

This type of ships are more complex both in construction and operation.so any error can lead to catastrophic consequences, because of the Passengers present in the ship.

1.3 The dangers of Ro-Ro ships

There is something about Ro-Ro ships that make them completely different from other types of ships. But we will come to it a bit later, after knowing the broad categorization of ship types by IMO according to freeboard and subdivision. IMO has classified ships into Class A and Class B. The Class A ships are those which have lesser sea openings and better protected from the sea, also because of stringent subdivision restrictions. But Class B ships are those which have higher freeboard and are directed by less stringent subdivision rules. Now, RORO ships are of Class B, but what yet sets them different is that they have a completely open vehicle deck extending right from the fore to aft, without any transverse subdivision bulkheads in between.

Image credits: pete / wikipedia

The reason behind this is very simple, yet unavoidable- to make access of cars (and other vehicles) possible from the forward to aft ends of the ship. Let's take a look at some of the main concerns regarding Ro-Ro ships:

No Subdivision Bulkheads
The problem with not having transverse subdivision bulkheads is actually an adverse one, given the circumstances. Transverse bulkheads are basically incorporated to maintain the damaged stability or water-tight integrity of the ship, in case of flooding of any of the compartments. Simple, that two consequent bulkheads shall limit the water flooding within themselves, and thus help the ship being stable even in case of some damage. But here's what happens if water enters a RoRo ship- The flooding starts progressing. How? Consider than there has been a damage in any part of the ship, due to which, water starts flooding in it. Since the only restrictions are the aft and bow doors, the water actually starts progressing along the entire length of the ship. Sounds bad, but is actually worse. Why? Read on.

Risk of Progressive Flooding

Due to absence of subdivisional bulkheads, the water progresses along the length of the ship. This not only causes the ship to lose its inherent buoyancy, but adversely affects its stability because of increasing free surface effect. In case of a single compartment damage, as in case of any other ships, the free surface created by one or two compartments is lower than what is created in an entire Ro-Ro ship, as the free surface area in this case is much more, due to the absence of transverse bulkheads. As a result, the ship loses its stability more rapidly that we generally expect it to do so. However, even in case the ship is not damaged, a Ro-Ro ships always stands at a higher risk of reduced stability.

Problem of Maintaining Stability

Every Ro-Ro ship, being a Class B type, has considerable freeboard, which means it operates at a low draft. These ships are also featured with multi-tier decks for accommodation of cars, trailers and trains, therefore requiring higher overhead clearance. Due to this, the depth of these ships is very high, owing to a high depth to draft ratio. Cargo is stowed up to the top-most deck, resulting in the rise in the accommodation deck. As a result of the increased depth to draft ratio, such ships are very sensitive to heeling moments, and a heeling moment cannot only be created by wind gusts or waves, but also internal cargo shifting. Thus, cargo latching and locking systems must be regularly checked and ensured so as to prevent cargo shifts during voyages. Also, heeling moments in lightship condition are prevented by incorporating heeling tanks at port and starboard sides. There have been many accidents of Ro-Ro ships which have caused due to rapid heeling moments, giving the crew very less time for proper evacuation. The disasters of MV Sewol (Korea, 2014) and MS Express Samina (2000) were basically due to the above explained theory. These ships being Ro-PAX had cost lives more than that of just the crew.

Image Credits: wikimedia.org

Ro-Ro are Stiff Ships

Though this is a lot related to stability, but it’s interesting to discuss it separately. The steel structure of Ro-Ro ships is designed to have a very low centre of gravity, as cargo is loaded up to the top most deck, this would offset the rise in centre of gravity. But due to the risk of rapid heeling, the overall centre of gravity of Ro-Ro ships are kept considerably low. Though this is stable, it laces a problem with itself. A reduced Centre of Gravity (CG) will always tend to decrease the rolling period of the ship. So if you're sailing on the ship itself, you'll feel that the ship is rolling too fast. It is true, that once it rolls, it will come back to its upright position rapidly (which means it is quite stable), but the rapid motions will cause you motion sickness. We call such ships to be stiff. This may also cause high stresses on the cargo lashing systems.

Problem of Cargo Doors

Other than doors on the port and starboard sides, Ro-Ro ships also have aft or bow doors with ramps, for heavier cargo to be loaded from the port. Both these door types have had their individual kind of problems as discussed further:

1. ***Stern Cargo Door:*** Stern cargo doors are generally very close to the waterline of the ship. There have been cases, when the stern door was not locked properly (which is basically a human error, since improper locks are notified by the ship's systems). Guess what could have happened next? As the ship moved into the sea, the improperly locked stern door served as the source of water ingress. Though, this is a human error, several efforts to alter the design of these doors have been made, but it is nearly impossible to place such doors high above the waterline, as that would not be feasible for easy cargo loading when the ship extends her ramps onto the port.
1. **Bow Door:** Many Ro-Ro ships have bow doors, i.e. the bow of the ship is itself a hydraulically hinged structure which acts as a door, from which a ramp extends out for cargo flow in and out of the ship. One of the worst maritime accidents has occurred due to the failure of this very system- on board MV Estonia in 1994. Let's look at it this way. The bow of the ship is vulnerable to the waves as the ship surges. Since this goes on continuously since the ship has set sail, the material on the bow of the ship experiences fatigue. In case of MV Estonia, the bow door mechanism had undergone fatigue (which should have been replaced during surveys) and ultimately, it gave away. The bow door separated from the ship's hull, ultimately leading in progressive downflooding, which resulted in sinking. But even then, the inherent problem of "rapid heeling" existed, and as a result the time available for evacuation was insufficient.

Image Credits: Mattes / Wikipedia

Location of Lifeboats

This is a matter of concern, especially for Ro-Ro Passenger ships. As we've known that Ro-Ro ships inherently have a considerably high freeboard, it is important to note the risk attached to it. In case of rapid sinking, there have been cases when the lifeboats could not be successfully deployed from the embarkation deck due to its height from the waterline. It is due to this risk, recent Ro-PAX ships are also equipped with inflatable chutes, which help the passengers to slide down from the embarkation deck, in case the deployment of lifeboats are impossible.

Image credits: Dozenist / Wikipedia

So isn't it interesting to note a paradox in the entire topic? Most of these risks are actually not related to a fault in design, yet they demand changes in the current designs. Ship designers are yet to find design solutions to all the above risks, especially the problem with maintaining the stability of these ships, without hampering the ease of operation and function ability of the vessel. In important inclusion in the design of the decks is the improvement of drainage systems on car decks. In some cases, the crew was not fluent with a uniform language of communication, which resulted in miscommunication during evacuation processes. Such factors have been made compulsory by SOLAS amendments. Recent efforts have ensured installation of automatic/computerized crisis management systems on board, which helps the crew decide the steps to be followed in case of any threat to the survivability of the ship. The industry is currently focussed a lot on improving the propulsion systems used by these ships. However, given the number of disasters related to Ro-Ro ships in the past, it is necessary that more efforts must go into improving their designs so as to eradicate the factors which pose threat to the safety of these ships.

CHAPTER 2

Worldwide Ro-Ro fleet, cost accounting of Ro-Ro ships

2.1 List of worldwide Ro-Ro fleet

RO-RO Cargo Vessel

27000 DWT

Builder / Yard No.: Shipyard 3. MAJ / 2788

Owner / Flag: CMA-CGM / BAHAMAS

Designed by: Shipyard 3. MAJ

The vessel is RO-RO ship suitable to carry containers, trucks, trailers, general cargo and cars and vans on hoistable deck Cargo space is divided into two (2) forward cargo holds with 40' cellguides and one (1) cargo space divided with decks into three (3) garages, and cargo space on weatherdeck with container fittings. Double bottom and side arranged for ballast water, HFO and antiheeling tanks. The ship's hull is specially equipped for in-water surveys. Engine room is equipped for unattended operation.

Car Truck Carrier

7000 cars

Builder: Shipyard ULJANIK

Owner / flag: Bahamas

Project No. 11303

Designed by: Shipyard ULJANIK

The vessel is suitable for world wide transport of passengercars and trucks on thirteen cargo decks, of which two arehoistable decks. It is divided by six watertight bulkheadsforming fore peak, deep tank, three cargo holds, engine roomand after peak and by two/gas tight decks and one freeboarddeck.

RO PAX

3000 lm

Builder: Shipyard ULJANIK

Project No. CONCEPT

Designed by: Shipyard ULJANIK

The vessel is suitable for worldwide transport of passengers, trailers and cars. Cargo area will consist of three decks for trailers and one separate deck for cars/vans. Structural arrangement to be based on longitudinal framing system with transversally framed side shell.

Car-Truck Carrier

4900 cars

Builder / Yard No.: Shipyard 3. MAJ / 705

Name: STX BLUEBIRD

Owner / Flag: NSC/Liberia

Designed by: Shipyard 3. MAJ

Sister ships: 705, 706, 707

Delivered: 2008

The ship is roll on/roll off car & truck carrier, suitable to carry passenger cars, pick up vans, container loaded on MAFI trailers and trucks built for unrestricted ocean services notation in world service. The vessel single screw diesel propulsion unit with engine room located aft. Cargo area below freeboard deck consists of four compartments (holds). Cargo area included 11 decks, two of them hoistable, one with one working position and one with two working positions. Parking area is for abt. 4,870 standard cars regardless to the orientation (longitudinal or transverse). The accommodation is arranged forward. One bow thruster abt. 1,000 kW is provided. The ship's hull is specially equipped for in-water surveys. Engine room is equipped for unattended operation.

Car Truck Carrier
Owner / flag: Bahamas

Builder / Yard No.: Shipyard ULJANIK / 477,478

Designed by: Shipyard ULJANIK

Project No. 11903 B

The vessel is suitable for world wide transport of passanger cars and trucks on 11 cargo decks, of which two are hoistable decks. Cargo area below freeboard deck will consist of two compartments, divided from each other by watertight bulkhead. Cargo area will have 11 decks for vehicle stowage while decks No.5 and 7 will be hoistable. Decks no. 4 and 6 will be reinforced for stowage of trucks. Structural arrangement to be based on longitudinal framing system with transversally framed side shell.

RO-RO Passenger Ferry
100 cars / 600 passangers

Builder / Yard No.: ShipyardKRALJEVICA/535
Name: SV. KRŠEVAN

Delivered:2005

The ship is designed as double ended Ro - Ro and passenger ferry propelled by two propelling units one on each bow/stern side of the ship. The ship will be intended for transport of passengers and vehicles as well as packed dangerous cargoes loaded on the vehicles, navigating in coastal area 6, with duration of voyage up to 90 minutes. The ship has open garage deck (main deck) for trailers and car transportation and for cars on hydraulically operated movable platforms. The Concept is based upon the idea of modern "drive through" ferry for loading and unloading of vehicles and passengers in the shortest period. The ship is equipped with hydraulically operated bow and stern ramps

RO-RO Passanger ferry Builder / Yard No.: ShipyardKRALJEVICA/ 536

130 cars/ 1200 passangers Name: MARJAN

Delivered:2006

The ship is designed as double ended Ro - Ro and passenger ferry propelled by two propelling units one on each bow/stern side of the ship. The ship will be intended for transport of passengers and vehicles as well as packed dangerous cargoes loaded on the vehicles, navigating in coastal area 6, with duration of voyage up to 90 minutes. The ship has open garage deck (main deck) for trailers and car transportation and for cars on hydraulically operated movable platforms. The Concept is based upon the idea of modern “drive through” ferry for loading and unloading of vehicles and passengers in the shortest period. The ship is equipped with hydraulically operated bow and stern ramps

2.2 Worlds largest ro-ro vessels

This is the world's Largest Short Sea Ro-Ro Vessel Named MV Celine

Image Courtesy: CldN, Port of Dublin

MV Celine, the world's largest short sea Ro-Ro ship, was christened on Friday, April 20, in Dublin Port.

With a capacity of 8,000 lane-meters, the super ferry, owned by Luxembourg-based CLdN, will be servicing Dublin Port as part of the multi-million-euro ABR Project to futureproof Dublin Port.

Under the program, work has started on three kilometers of new berths to welcome the new ships.

The 235-meter long ship was constructed in South Korea's Hyundai Mipo Shipyard before being deployed to its homeports of Zeebrugge and Rotterdam. The vessel features a dual propulsion system allowing for emissions reduction. Luxembourg-based short sea specialist CLdN RoRo took delivery of the vessel in October 2017.

MV Celine was joined by a second 8,000 lane-metre vessel, MV Delphine, in January 2018 as the company further expands its fleet and operations in Europe.

CLdN currently operates 25 Ro-Ro vessels, offering weekly sailings between the ports of Zeebrugge, Rotterdam, London, Killingholme, Dublin, Gothenburg, Esbjerg, Hirtshals, Santander, Porto, Flushing and Dagenham

Image Courtesy: CldN, Port of Dublin

CLdN commenced services to Dublin Port in October 2009 and as the Irish economy recovered, these have grown to seven calls weekly from Zeebrugge and Rotterdam. Namely, the company's direct freight services to Continental Europe is warmly welcomed by importers and exporters especially with the reality of Brexit looming. Under its masterplan, Dublin Port is investing EUR 132 million in infrastructure and additional capacity. A capital investment of EUR 1 billion is planned over the next decade. Cargo volumes at Dublin Port grew by 3.4 pct in Q1 2018 to exceed nine million gross tonnes for the quarter. Most of the port's cargo is comprised of freight trailers and containers and both sectors showed continued strong growth, with Ro-Ro up by 2.5 pct and Lo-Lo container volumes ahead by 5.3 pct. On the passenger and vehicle side of the business, imports of trade vehicles in the first three months jumped by 14.2 pct, while passenger volumes climbed by 8.6 pct.

The following is another of the world's largest Ro-Ro vessels, the Wilh. Wilhelmsen group has launched its 150th anniversary vessel, MV Tønsberg, into operation. The Mark V class is the most sophisticated vessel ever built in the roll-on roll-off segment.

The Mark V vessel is the largest of its kind, with a length of 265 metres offering a cargo volume of 138 000 cubic metres over six fixed and three hoistable decks. The pioneering roll-on/roll-off vessel is built at Mitsubishi Heavy Industries in Nagasaki, Japan. Four Mark V vessels will be delivered to Wilh. Wilhelmsen ASA and its partner Wallenius Lines. The second vessel will be delivered in August and two in 2012. Wilh. Wilhelmsen technical department developed the design in close cooperation with the shipyard and has been responsible for follow-up of the construction work at the yard.

Built for larger, heavier cargo

Wilh. Wilhelmsen ASA experienced a strong rebound in its shipping operations last year, with a 25% increase in transported volumes in 2010 compared with 2009. The entire cargo hold of the MV Tønsberg is arranged for customer's high and heavy cargo such as excavators, bulldozers, wheel loaders and harvesters. With a width of 12 metres and safe working load of 505 tonnes, the vessel's stern ramp offers customers the possibility to ship larger units than ever before. The clear height of the main deck, 7.1 metres, is also unprecedented for this kind of vessel. Cargo can even be loaded on the weather deck, which has a ramp from the deck below. Three decks can be hoisted by electric winches to provide maximum flexibility and utilisation. MV Tønsberg will commence service in the Wallenius Wilhelmsen Logistics' round-the-world trade.

Designed for sustainability

The Mark V will use 15 to 20% less fuel per transported unit than its predecessors, thanks to optimised hull form and a number of energy saving features such as the streamlined rudder design and duck tail. In the engine room an advanced turbo generator produces electricity from the waste, exhaust heat. In total, these initiatives help to cut emissions significantly. A Unitor water ballast water treatment system avoids harmful transfer of microorganisms to the sea. Further, all fuel oil tanks are protected to minimise the risk of leakage in case of grounding or collision. MV Tønsberg is the fourth vessel with this name in the Wilh. Wilhelmsen fleet. It is named after the coastal town in Norway where Wilh. Wilhelmsen was founded in 1861. MV Tønsberg is the Wilh. Wilhelmsen group's 150th anniversary vessel. Manning and technical management will be performed by Wilhelmsen Ship Management Norway. MV Tønsberg will fly the Maltese flag, and be owned by Wilhelmsen Lines Shipowning Malta, which is owned by Wilh. Wilhelmsen ASA.

2.3 The LNG fueled ro-ro vessel named "El Coquí"

Some of the first liquefied natural gas (LNG)-powered, combination container and Roll-On/Roll-Off (ConRo) ships in the world, are designed especially for service between the United States and Puerto Rico. The Commitment Class ConRos, which will be named *El Coquí* and *Taíno*, are designed from the keel up to meet the needs of Crowley's shipping company customers. By making use of clean LNG as their primary fuel, the ships will offer a 35% reduction in CO_2 emissions per container as compared to existing fossil fuels. Built at VT Halter Marine shipyard in Pascagoula, Miss., and scheduled for delivery in the second half of 2017 and the first half of 2018, *El Coquí* and *Taíno* represent the next chapter in the company's distinguished, award-winning service for the people of Puerto Rico. Built in the U.S. and operated in the Jones Act trade, these new Crowley ships will offer optimal performance and safety while setting new standards for environmentally responsible shipping.

The ships, which are some of the world's first to be powered by LNG, are designed to travel at speeds up to 22 knots and carry containers ranging in size from 20-foot standard to 53-foot-long, 102-inch-wide, high-capacity units, along with hundreds of vehicles in enclosed, weather-tight car decking.

2.3.1 Machinery

The requirement to design a Vessel which is powered byenvironmental friendly technology played the key roleduring the project development. Besides the challenges derived from combining the RO-RO and the container vessel capability, the gas systemand its associated equipment was the major driverconstraining the vessel's arrangement and the overallconcept. A number of different machinery configurationoptions were investigated in order to find the optimumbetween CM's operational requirements and vesseldelivery. Based on the various options developed by WSD forCM's, the final decision was for single-screw propulsionwith 2-stroke low speed dual fuel High Pressure (HP)main engine and 4-stroke medium speed Dual Fuel (DF)auxiliary engines from MAN Diesel & Turbo (MAN),and FGSS including LNG tanks from TGE Marine GasEngineering (TGE) Amongst others, the Otto cycle DF options has not beenselected due to the higher natural gas consumption whichmeant less endurance for the same LNG bunker tankssize – already at their maximum allowable within theagreed reserved space i.e. below C/H No.4. While both Wärtsilä and MAN are striving hard toimprove the consumption on both natural gas and pilotfuel, an interesting finding is that above about 85%MCR,the 2-stroke Low Pressure (LP) engine used for thisproject showed better overall energy consumption.

The main machinery and fuelling system equipment canbe summarized as follows:

-Main engine, 1x 8S70ME-C8.2-GI

-Auxiliary engines, 3 x 9L28/32 DF

-LNG containment system, 3 x 770m3-Tank Connection Space (TCS)

-Pump room and compressor room or Gas HandlingRoom (GHR)

-HP FGSS to main engine

-LP FGSS to auxiliary engines-Gas Valve Unit (GVU)

-Bunkering station-Ventilation mast

2.3.2 Engine room design

The entire engine room and all the systems relating to theDF system are designed according to the Inherently SafeEngine Room concept, which in practice means thatdouble wall piping is applied where routed throughengine room (incl. enclosed spaces). The Vessel is propelled by a single low speed 2-strokedual fuel MAN engine located aft. Three (3) medium speed 4-stroke DF engines wereselected to provide electrical power generation, andarranged in the engine room. Only the emergencygenerator set is fueled only by ULSMGO. The LNG is supplied to the main engine at high pressure(abt. 300 bar) and to the auxiliary engines at low pressure(abt. 4 bar). The three (3) LNG tanks are meant to feedboth HP and LP systems. The HP and LP gas auxiliary equipment is placed in theGHR which is located on Portside, just aft of E/Rbulkhead (see 5.3). The gas supply line in the engine room to the DF enginesis designed with ventilated double-wall piping and gasdetectors for emergency shutdown. The purpose of theouter pipe shielding is to prevent gas outflow to themachinery spaces in the event of rupture of the inner gaspipe. Hence the annular space as well as spaces aroundvalves, flanges etc. are equipped with separatemechanical ventilation (30ch/hr) from a non-hazardousarea (outside engine room). All gas related piping is of stainless steel. Permanently installed gas detectors are fitted in the TCS,Tank Hold Space (THS), in all ducts around gas pipes, inengine rooms, ventilation trunks, compressor rooms, andother enclosed spaces containing gas piping or other gasequipment. The exhaust system is designed and built slopingupwards in order to avoid formations of gas fuel pocketsin the system.

2.3.3 Structure and stability

The main challenge when checking the stability of thevessel was to find the balance between reasonable GMvalue, trim restrictions, amount of ballast used duringvoyage and strength limitation coming from the highbending moment. The task turned out to be even morecomplicated when different combinations of containertypes (standard, high cube) and sizes (40ft, 45ft and 53ft)had to be calculated. The requirement of having longer holds suitable foraccommodating 45ft and 53ft containers and large heavyaft body (RO-RO space with container stacks on top)played the major role both in Vessel’s arrangement andstructural configuration, bringing to the Vessel an unevenlightship weight distribution. Normally for the calculation purposes homogeneousweight is taken into account for all containers.A homogeneously loaded vessel does not feature majordeviations from hull stresses present in conventionalcontainerships. Nevertheless, as operational requirement,it was needed to optimise the ship for very specificloading scenario:

-40/45ft containers: 23 t/unit

-53ft containers: 16 t/unit

Such loading can be beneficial in respect to an even trimof the vessel, which was among the requirements for theVessel when calling Jacksonville harbour where due toharbour restrictions, at 10.0m scantling draught thevessel is not allowed any trim. Hence the trim aft, whichpossibly could contribute to lower the hull stresses wasnot permitted. High hogging moment appeared as a result of light 53ftcontainers, prescribed to be carried in the central part ofthe vessel. At the same time with accommodation locatedsemi-aft it was a need to load more heavy containers inthe aft part. Supported by the maximum buoyancy in themiddle area of the hull and very little buoyancy in the aftpart bending moment had raised considerably. Finally thebalance between optimised structural arrangement of themidship section able to withstand required bendingmoment, maximum number of containers loaded in thepredefined way and minimised ballast capacity has beenfound. Moreover a number of iterations were made in order tofind the optimum combination between LNG tanksposition and cargo holds setup with respect tominimizing the bending moments. The implications on the arrangement listed above led toextensive hogging and higher bending moments, abt.35%higher than the standard Rule values. Therefore, optimisation of midship section and allstructural members was needed from the very beginningof the project development phase, prior to start withClass drawings. The accuracy of the weight distribution resulted to becritical in this specific design as well as LSW influencesdirectly the DWT and the related penalties; hencestructure was modelled in NUPAS for verificationpurposes. In this way detailed weight monitoring wasestablished from the very beginning of the project. Such extensive naval architecture investigations prior toContract signing reduces the risks.

CHAPTER 3

(IMO AND SAFETY)

3.1 IMO and Ro-Ro safety

The roll-on/roll-off ship1 is one of the most successful types operating today. Its flexibility, ability to integrate with other transport systems and speed of operation have made it extremely popular on many shipping routes.

The roll-on/roll-off ship is defined in the November 1995 amendments to Chapter II-1 of the International Convention for the Safety of Life at Sea (SOLAS), 1974 as being "a passenger ship with ro-ro cargo spaces or special category spaces..."

One of the ro-ro ship's most important roles is as a passenger/car ferry, particularly on shortsea routes. But despite its commercial success, the ro-ro concept has always had its critics. There have been disturbing accidents involving different types of ro-ro ship, the worst being the sudden and catastrophic capsizing of the passenger/car ferry Herald of Free Enterprise in March 1987 and the even more tragic loss of the Estonia in September 1994.

3.1.1 IMO's activities in the area of Ro-Ro safety

Since coming into being in 1959, IMO has adopted numerous international conventions and other instruments which are designed to improve maritime safety in general. Some of these are particularly relevant to ro-ros.

The International Regulations for Preventing Collisions at Sea, 1972, for example, contain a series of measures to improve the safety of shipping in confined waters, such as straits and narrow channels. These include the introduction of traffic separation schemes and other routeing measures. Ro-ros, such as passenger ferries, frequently operate in such waters which are not only confined but are frequently congested as well.

These measures have been very successful in reducing collisions, especially head-on collisions. Studies made of collisions in the English Channel, for example, show that the collision rate has been cut dramatically since the 1960s and there can be little doubt that these measures have saved many ro-ro ships operating on the short-sea crossing between the United Kingdom and the Continent from accidents.

Other important conventions which are relevant to safety include the International Convention for the Safety of Life at Sea, 1960 and 1974, the International Convention on Load Lines, 1966, and the International Convention for Safe Containers, 1972.

However, since the early 1970s, when ro-ros were appearing in increasing numbers, IMO has developed various measures with the special features of ro-ro ships in mind. These are dealt with below under different subject headings.

3.1.2 Subdivision and damage stability

The feature which distinguishes the ro-ro ship from other types is the open vehicle deck (or decks) which run the full length of the ship with a door at either end. It is crucial to the whole ro-ro concept - and one of its most controversial features, since it has led to considerable concern about the safety of ro-ro ships is their stability in both the intact and damaged condition.

Under the International Convention on Load Lines, 1966, ships are divided into two basic types: type A ships include tankers, which are assigned lower freeboards than type B ships. Type A ships are better protected from the sea because they have more internal subdivision and fewer surface areas for openings. Dry cargo ships, including ro-ro ships, are type B with larger freeboards and are subject to less stringent requirements for subdivision and damage stability.

As far as SOLAS is concerned, subdivision and damage stability requirements for passenger ships are contained in part B of chapter II of the 1960 version and chapter II-1 of the 1974 version. In both, the standard of subdivision varies according to the length of ships and the number of passengers on board. Passenger ships are defined as ships which carry more than 12 passengers.

This is important as far as ro-ros are concerned because it means that passenger ferries, including car ferries, are classed as passenger ships. The most important result of this is to make it mandatory for passenger car ferries to be constructed in such a way that the deck on which the vehicles are parked is above the waterline. The area beneath this deck must be subdivided by vertical watertight bulkheads.

The 1960 SOLAS Convention used what is known as the deterministic method. This lays down precise calculations for determining such parameters as the permissible length of compartments, special requirements concerning subdivision, stability in a damaged condition, and other factors.

However, many authorities felt that the deterministic method was far from ideal. In 1973, therefore, the IMO Assembly adopted resolution A.265(VIII), entitled Regulations on Subdivision and Stability of Passenger Ships. This was intended as an equivalent to part B of chapter II of SOLAS 60 and when the 1974 Convention was adopted a reference was made to the requirements of this resolution which may be used instead of those contained in part B.

Resolution A.265 uses a completely different approach known as the probabilistic method. This tries to establish the probability of the ship surviving in the event of certain damage occurring.

The degree of subdivision required for each ship is determined by a formula known as required Subdivision Index R. This is so calculated that the degree of safety required increases with the number of passengers carried and the length of the ship. Further regulations contain formulae for calculating the probable effect on stability if certain damage occurs. These formulae can be used to calculate the attained Subdivision Index A. The ship's degree of subdivision is considered sufficient if the stability of the ship in a damaged condition meets the requirements of the regulations and the attained Subdivision Index A is not less than Subdivision Index R.

Guidance Notes issued by IMO to help application of these requirements state that the attained Subdivision Index A 'is based on the concept of the probability of survival of the ship in case of collision'.

The notes state:

'In order to develop this concept it is assumed that the ship is damaged. Since the location and size of the damage is random, it is not possible to state which part of the ship becomes flooded. However, the probability of flooding of a space can be determined if the probability of occurrence of certain damages is known; the probability of flooding a space is equal to the probability of occurrence of all such damages which just open the considered space. Thereby a space is a part of the volume of the ship which is bounded by undamaged watertight structural divisions.

'Next it is assumed that a certain space is flooded. In addition to some invariable characteristics of the ship, whether the ship can survive flooding depends, in such a case, on the initial draught and GM2, the permeability of the space and the weather conditions, which are all random at the time when the ship is damaged. Provided that the limiting combinations of the aforementioned variables and the probability of their occurrence are known, the probability that the ship with the considered space flooded will not capsize or sink can be determined.

'The probability of survival is the sum of the products for each compartment or group of compartments of the probability that a space is flooded multiplied by the probability that the ship will not capsize or sink with the considered space flooded.'

Whether they are built according to part B in chapter II of SOLAS 74 or resolution A.265, the fact that they are classified as passenger ships means that car ferries are constructed in such a way that the vehicle deck is above the water line. The area below the vehicle deck is subdivided. This means that if the ship is holed in a collision the water which enters will be retained either permanently or for some time by the vertical bulkheads. Even if the damage is so great that the ship eventually sinks, it will generally do so slowly enough for those on board to be evacuated safely.

By the early 1970s more and more ro-ros were being built for the carriage of goods vehicles and containers rather than private cars and ordinary passengers. Many of those engaged in this growing trade felt that existing IMO requirements were unnecessarily stringent. In 1973 some delegations maintained at a meeting of IMO's Maritime Safety Committee (MSC), that the drivers of goods vehicles were not passengers but were on board the ship in order to pilot cargo. They should therefore be regarded as engaged on board on the ship's business.

Had this opinion been accepted it would have meant that ro-ro ships designed for the carriage of goods vehicles and carrying 12 or more drivers would no longer have been classed as passenger ships. They could have been so constructed that they could incorporate another vehicle deck below the bulkhead deck (and below the waterline) without any transverse subdivision bulkheads besides machinery space and pier bulkheads being required. Watertight subdivision would then have been formed mainly by the longitudinal bulkheads.

The MSC decided by a majority that drivers should not be regarded as part of the crew. But it did recognize that the existing requirements for subdivision by unpierced bulkheads imposed severe constraints on ro-ro designs which might not be necessary. The reasoning behind this was that drivers are generally able-bodied and used to being on board ship: they are likely to be able to cope with an emergency better than the average ferry passengers, who might include women, children, elderly and infirm people.

It was decided that the matter should be further considered and in 1975 the IMO Assembly adopted resolution A.323(IX) which permitted in passenger ships the fitting of bulkheads below the bulkhead deck with watertight doors designed to permit the movement of vehicles, on condition that other more stringent safety requirements were met. The Assembly recommended that amendments to the 1974 SOLAS Convention embodying these provisions be adopted upon its entry into force. This was done in the 1981 amendments to SOLAS which entered into force on I September 1984.

In 1976 the whole question of ro-ro safety was raised at the MSC by France in a comprehensive paper prepared by an Administrative Technical Committee set up specifically to investigate ro-ro safety. Its report contained a number of proposals for amending existing international regulations for cargo ro-ro ships together with suggestions as to how they might be improved. Several of these proposals concerned subdivision and stability requirements, one proposal being that a special type C category be created in the Load Line Convention to cover ro-ros which would give higher freeboard values than those of type B.

Some other delegations felt that while ro-ros were undoubtedly a specific type of ship this did not mean that they required special regulations. So were many other ship types, it was argued. It was, however, agreed that the matter should be studied carefully and the MSC referred the French report to a number of sub-committees.

The Sub-Committee on Subdivision, Stability and Load Lines considered the subject in October 1977 but decided that the subdivision, stability and load lines requirements of ro-ro ships did not require special consideration. Instead the matter should be pursued in the context of requirements for cargo ships in general.

Concern was expressed about dangerous situations that could arise, due to the free liquid surface effect, if loose water from leakage, fire-extinguishing water, etc. were present in enclosed spaces - such as the vehicle deck of a ro-ro ship which extends for a substantial proportion of the ship's length and which is not provided with internal subdivision. To solve this problem a circular was elaborated which provided requirements for the internal drainage of such spaces. These were adopted by the Assembly in 1983 as resolution A.515(13) and were included in the 1989 amendments to SOLAS.

In January 1984 the Sub-Committee (now renamed the Sub-Committee on Stability and Load Lines and on Fishing Vessels Safety), in line with its decision to develop subdivision and stability requirements for dry cargo ships including ro-ro ships, agreed to a proposal concerning a draft probabilistic method for testing subdivision and stability requirements for such ships. Members were invited to perform sample calculations on various types and sizes of ships using this method. In June 1986, the Sub-Committee drafted regulations which Member States were again requested to apply on a trial basis to appropriate ship-types and to submit results to IMO. The replies were still coming in when the Herald of Free Enterprise capsized in March 1987.

3.1.3 Fire safety

Fire safety The large open spaces associated with ro-ro ships also have implications as far as fire safety is concerned and this matter was considered by IMO as early as the 1960s.

In 1967 the Assembly adopted, with resolution A.122(V), a new regulation 108 as an amendment to the 1960 SOLAS Convention concerned with the protection of special category spaces above or below the bulkhead deck in passenger ships. The underlying philosophy was that normal main vertical zoning may not be practicable for such horizontally extended spaces. To enable the modification to the vertical zones concept, the Assembly also adopted, with resolution A.123(V), a Recommendation on fixed fire-extinguishing systems for special category spaces.

In November 1975 the Assembly adopted resolution A.327(IX), concerning fire safety requirements for cargo ships which recommends the implementation of improved fire safety requirements in addition to those incorporated in SOLAS 60 and SOLAS 74 (which at that time had not entered into force). It called upon IMO to continue working on the subject with a view to amending SOLAS 74 when it entered into force.

Regulation 18 of that resolution deals with cargo spaces intended for the carriage of motor vehicles with fuel in their tanks (which basically means ro-ro ships). It includes additional fire detection and alarm requirements, improved fire extinguishing arrangements, ventilation and precautions against the ignition of flammable vapours.

In view of this resolution the Sub-Committee on Fire Protection felt that there was no need for additional fire safety requirements for ro-ro cargo ships when the French paper was considered in July 1977. It was agreed, however, that resolution A.327(IX) might need to be amended and a special working group was established to consider the matter.

As a result, amendments to the requirements of chapter II-2 were incorporated in the 1981 SOLAS amendments, which entered into force on 1 September 1984. Several regulations concerning fire safety in cargo ships were affected by these changes, including regulation 53 (fire protection arrangements in cargo spaces), while a new regulation 54 was added dealing with special requirements for ships carrying dangerous goods. Specific reference is made to ro-ro ships.

Regulations 53 and 54 of chapter II-2 of SOLAS 74 were further improved in the 1983 SOLAS amendments and the 1989 SOLAS amendments which were adopted by the Assembly as recommendations in resolution A.515.

3.1.4 Cargo safety

Apart from stability, the problem which once created most concern in ro-ro shipping is cargo stowage and security. The det Norske Veritas study quoted earlier showed that 43% of ro-ro losses could be attributed to shift of cargo and operational faults.

A survey of ro-ro damage in the Channel and Mediterranean, carried out by the French marine insurance market and quoted in Lloyd's List in January 1984, stated that at least half could be attributed to inadequate or defective securing of vehicles or their cargo.

And another survey carried out by the United Kingdom Department of Trade and Industry in 1979 of 26 ro-ro ships, including some passenger car ferries, showed that 12 had suffered accidents resulting from the shifting of cargo following the failure of security arrangements. Of these, nine were said to be minor in nature, but three were serious and resulted in extensive damage to vehicles and cargo. The survey, incidentally, was carried out because the Department had become concerned by the frequency of such incidents in the previous two years.

Among the difficulties which cargo stowage presents to the ro-ro operators are the following:

- 1. Stowage of cargo on deck: since the cargo is driven on and off the ship and, once on board, stowed tightly together, it is often difficult to position the lashings and other arrangements for securing the cargo in the best possible locations.

- 2. The variety of vehicles and cargo carried: ro-ro ships have to be able to carry many different types of wheeled cargo from small cars to 45-ton trailers and, in special cases, loads of several hundred tons. It is almost impossible to devise a lashing system which is ideal for all of these cases.

- 3. The design of trailers and containers: trailers which are carried on ro-ro ships are not normally designed primarily for this use. The fact that they occasionally have to be carried by sea is often of secondary importance to the land operator who is not always aware of the forces which act upon the ship and its cargo.

- Since trailers and lorries are designed primarily for road usage they very often lack adequate securing points, which makes it difficult to secure trailers to the ship. An additional complication is the trailer's suspension system, which may cause the lashings to become disengaged if proper precautions are not taken.

- 4. Securing the cargo within the unit: containers and other units carried on ro-ro trailers are frequently sealed when they leave the place where they are loaded and they are not opened again until they arrive at their final destination. This is done for reasons of security and also to satisfy customs regulations. But it means that the crew of the ship and the port staff responsible for loading it are unable to examine the cargo to make sure that it is properly secured. They are dependent on the skill and diligence of people who very often have no knowledge of the forces which may be encountered on board a ship in rough seas.

- 5. The lack of transverse bulkheads on board ro-ro ships means that a relatively minor incident such as a trailer toppling over as a result of a defective lashing - can rapidly escalate into something more serious. Nearby units can be dislodged with the result that a series of units eventually fall like dominoes. Such shifts of cargo can cause severe stability problems for the ship.

- 6. It is difficult to arrange the best loading conditions since cargo units arrive at the port of embarkation in a random order and it is equally difficult for the crew to obtain detailed information about the vehicles, the cargo, weights, etc. in advance.

- 7. Stability and rolling periods: road trailers tend to have a very high point of gravity when they are loaded: the cargo may be stable on the trailer, but the trailer and cargo together are not necessarily very stable on the deck of the ship (or even on the road, as the number of overturned articulated lorries and trailers testifies).

Ro-ro ships themselves have a low centre of gravity. This results in a rolling period (i.e. the time taken for the ship to roll from the furthest point on one side to the furthest point on the other) of as little as seven seconds. This is very short, and the movement of the ship and its cargo is therefore very rapid. This can put a severe strain on lashings.

Since the 1970s, IMO has developed a series of measures to improve the safety of cargoes carried on ro-ro ships. In 1975, for example, IMO and the International Labour Organisation (ILO) began work on guidelines for training in the packing of cargo in freight containers. These were published in 1978 and were intended as a short guide to the essentials of safe packing for use by those responsible for the packing and securing of cargo in freight containers or vehicles.

The advice given in the guidelines refers to the packing of goods in containers but much of the advice applies equally to vehicles which are to make a ro-ro international voyage.

It is vital that containers and vehicles be properly packed, for sea voyages are made in a variety of weather conditions likely to exert a combination of forces upon the ship and its cargo. The guidelines state that these will give rise to pitching, rolling, heaving, surging, yawing or swaying forces or a combination of two or more. Such movements can exert forces on the cargo greater than those usually found ashore and may exert them over a prolonged period.

The importance of applying the provisions of the guidelines to vehicles was highlighted by a report to the Sub-Committee from Sweden of a survey in which loaded vehicles leaving Swedish roro terminals had been spot-checked as to the securing of their cargoes.

Out of 535 loaded vehicles, fewer than 300 had been found to conform with the Swedish regulations concerning cargo securing on road vehicles. Thus 45% of the cargo on road vehicles had been found to be partly or completely unsecured.

In 1985 IMO and ILO issued revised Guidelines for Packing of Cargo in Freight Containers or Vehicles. The observer of the International Confederation of Free Trade Unions stated that the

revised guidelines would make a valuable contribution to raising safety standards in the port and transport industries. A survey of the experience of its union members with containers had indicated that whilst the introduction of containers has served to eliminate accidents associated with traditional methods of cargo handling, those accidents which occur in container handling are more serious in extent and degree. The packing of containers is frequently a contributory factor and when it is done badly the dockers and seafarers suffer.

The guidelines state: 'Packing and securing of cargo inside a container or vehicle should be carried out with this in mind. It should never be assumed that the weather will be kindly and the sea smooth or that securing methods used only for land transport will always be adequate.

'Whilst the use of freight containers substantially reduces the physical hazard to which goods are exposed, improper or careless loading of goods into a container may be the cause of personal injury when the container is handled or transported; in addition, serious and costly damage may occur to the goods inside or to equipment. The person who packs and secures goods into the container for export may be the last person to look inside the container until it is opened by the consignee at its final destination. Consequently, a great many persons will rely on his skill: road vehicle drivers and other highway users when the container is carried by road, railway personnel and others when the container is carried on a rail-car, dock workers when the container is lifted on or off a ship, and crew members of the ship which may be taking the container through its most difficult conditions; as well as shippers and consignees, etc. All may be at risk from a poorly packed container, in particular, one which is carrying dangerous goods.'

By 1981 the Assembly adopted guidelines on the safe stowage and securing of cargo units and other entities in ships other than container ships (resolution A.489 (XII).

The guidelines are intended for use in connection with wheeled cargoes, containers, flats, pallets, portable tanks, packaged units, vehicles, etc. and parts of loading equipment which belong to the ship but are not fixed to the ship.

One of the most important recommendations made is that ships should carry a Cargo Securing Manual 'appropriate to the characteristics of the ship and its intended service, in particular the ship's main dimensions, its hydrostatic properties, the weather and sea conditions which may be expected in the ship's trading area and also the cargo composition'.

To assist Governments in the development of these Manuals, the Sub-Committee prepared a number of provisions to be included. These were issued as MSC/Circular 385 in January 1985.

The provisions are intended to provide a uniform approach to the preparation of Cargo Securing Manuals, their layout and content. The subjects covered include details of fixed cargo securing arrangements and their location; location and stowage of portable cargo securing gear and its correct application; inventory of items provided; and an indication of the magnitude of forces expected to act on cargo units in various positions on board the ship.

In February 1982, work began on developing a resolution on elements to be taken into account when considering the safe stowage and securing of cargo units and vehicles in ships. This was adopted in November 1983 as resolution A.533(13) which recognizes that cargo 'is stowed on and secured to cargo units and vehicles in most cases at the shipper's premises ... and that the cargo on cargo units and vehicles may not always be adequately stowed or secured for safe sea transport'.

The resolution covers elements to be considered by the shipowner and shipbuilder, the master of the ship and finally the shipper, forwarding agents, road hauliers, stevedores and port authorities.

IMO also developed guidelines for securing arrangements for the transport of road vehicles on ro-ro ships. A resolution on this subject (A.581(14)) was adopted by the Assembly in November 1985.

The guidelines are intended to apply to commercial vehicles, including semi-trailers and road trains, with a total mass (including cargoes) of up to 40 tons, and articulated road trains of not more than 45 tons. They do not apply to buses.

The resolution says that given adequately designed ships and properly equipped road vehicles, lashing of sufficient strength will be capable of withstanding the forces imposed on them during the voyage. The side guards often required for vehicles can obstruct proper securing and the guidelines take this difficulty into account. They cover securing points both on the deck of the ship and on the vehicle, as well as lashings and stowage.

The Sub-Committee on Containers and Cargoes continued its work in this field, concentrating on two main areas. One was the development of a harmonized calculation method for determining accelerations acting on cargo units, including vehicles, on board ship.

The second and more important was the development of a Code of Safe Practice for the Safe Stowage and Securing of Cargo, Cargo Units and Vehicles. The aim of this code is to advise masters on the specific hazards and difficulties associated with the transport of certain cargoes; the stowage and securing of such cargoes; and associated ship handling measures.

The Sub-Committee also began work on a a new revised chapter VI of SOLAS 74 with the intention, among other things, of making elements of the code mandatory. But before this work could be completed an event occurred which was to have a major impact upon IMO and the whole ro-ro trade.

3.2 The Herald of free enterprise disaster

In March 1987 the roll-on/roll-off passenger ferry Herald of Free Enterprise capsized and sank shortly after leaving Zeebrugge in Belgium. The accident occurred because the bow door was left open when the ship left port allowing water to enter and flood the car deck. The accident resulted in the deaths of 193 passengers and crew members.

It was not the first time that a ro-ro ship had capsized but the circumstances of the disaster not least the dramatic photographs that appeared in the press and on television - made a strong impression on public opinion.

Shortly after the accident the United Kingdom came to IMO with a request that a series of emergency measures by considered for adoption. Most of these consisted of proposed amendments to the International Convention for the Safety of Life at Sea (SOLAS), 1974, the most important treaty dealing with the safety of the world's ships. It has so far been ratified by 128 countries and applies to 98% of world merchant tonnage.

The proposals, many of which were based on the findings of the inquiry into the disaster, were presented to IMO in separate packages, the first of which was adopted by the MSC in April 1988.

1. The 1988 (April) amendments to SOLAS

The amendments affect regulations 23 and 42 of Chapter II-1 of the SOLAS Convention. The first deals with the integrity of the hull and superstructure, damage prevention and control and involves the addition of a new regulation 23-2 which requires that indicators be provided on the navigating bridge for all doors which, if left open, could lead to major flooding of a special category space or a ro-ro cargo space.

The same regulation also requires that means be arranged, such as television surveillance or a water leakage detection system, to provide an indication to the navigating bridge of any leakage through doors which could lead to major flooding.

Special category and ro-ro spaces must also be patrolled or monitored by effective means, such as television surveillance, so that undue movement of vehicles in adverse weather, fire, the presence of water or unauthorized access by passengers can be observed whilst the ship is underway.

A new regulation 42-1 deals with supplementary emergency lighting for ro-ro passenger ships. All public spaces and alleyways must be provided with supplementary lighting that can operate for at least three hours when all other sources of electric power have failed and under any condition of heel.

A portable rechargeable battery-operated lamp must be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting is provided.

The amendments entered into force on 22 October 1989 under a procedure known as "tacit acceptance." This normally results in amendments entering into force within two and a half years of the date of adoption by the MSC, but Article VIII does allow the Committee to select a different period of time and this was the first time that the procedure had been used to reduce the period before entry into force to less than two years. The amendments entered into force only 18 months after adoption - an indication of the great importance which IMO attaches to ro-ro safety.

2. The 1988 (October) Amendments

In October 1988 the MSC met again in a special session requested and paid for by the United Kingdom to consider a second package of amendments arising from the Herald of Free Enterprise tragedy. The amendments adopted entered into force on 29 April 1990. They became known as the "SOLAS 90" standard.

One of the most important amendments concerns regulation 8 of Chapter II-1 and is designed to improve the stability of passenger ships in the damaged condition. Work on the amendment had actually begun some years before following an accident involving another ro-ro ship. This was the European Gateway, which capsized following a collision with another ship in 1982. Like the Herald of Free Enterprise five years later, the European Gateway ended up lying on her side in relatively shallow water and only five lives were lost. The adoption of the amendments was brought forward because of its relevance to ro-ro safety.

The amendment applies to ships built after 29 April 1990. The amendment considerably expands the existing regulation and takes into account such factors as the crowding of passengers on to one side of the ship, the launching of survival craft on one side of the ship and wind pressure. The amendment stipulates that the maximum angle of heel after flooding but before equalization shall not exceed 15 degrees.

A research programme set up by the United Kingdom Department of Transport analysed the new standard and the Steering Committee carrying out the study reported that SOLAS 90 "should provide an adequate standard of protection against capsize up to sea state 3, i.e. in moderate seas having a significant wave height3 up to 1.5m. This is an important finding and one which appears to validate SOLAS 90 as a standard that should enable ro-ro ferries and any other conventional design of passenger ship to survive the effects of prescribed damage in such seas."

A further amendment to regulation 8 was proposed by the United Kingdom. It is concerned with intact rather than damage stability. It requires masters to be supplied with data necessary to maintain sufficient intact stability and the amendment expands the section by requiring that the information must show the influence of various trims, taking into account operational limits.

Ships must also have scales of draught marked clearly at the bow and stern. Where these are not easily readable the ship must also be fitted with a reliable draught indicating system. After loading and before departure the master must determine the ship's trim and stability.

The next amendment adds a new regulation 20-1 which requires that cargo loading doors shall be locked before the ship proceeds on any voyage and remain closed until the ship is at its next berth.

Another amendment affects regulation 22 and states that at periods not exceeding five years a lightweight survey must be carried out to passenger ships to verify any changes in lightweight displacement and the longitudinal centre of gravity. The lightweight of a ship consists of the hull, machinery crew and fittings without fuel and stores. Additions to the structure can add significantly to lightweight and affect the ship's stability.

3. The April 1989 Amendments

Further amendments to SOLAS were adopted by the MSC in April 1989. They also entered into force on 1 February 1992.

Several regulations of Chapter II-1 were amended, the most important being regulation 15 which deals with openings in watertight bulkheads in passenger ships. From 1 February 1992 new ships have had to be equipped with power-operated sliding doors, except in specific cases and must be capable of being closed from a console on the bridge in not more than 60 seconds. The amendments make it clear that all watertight doors must be kept closed except in exceptional circumstances.

4. The May 1990 Amendments

Important changes were made to the way in which the subdivision and damage stability of cargo ships (including freight-only ro-ro ships) is calculated. They apply to ships of 100 metres or more in length built after 1 February 1992.

The amendments are contained in a new part B-1 of Chapter II-1 and are based upon the socalled "probabilistic" concept of survival, which was originally developed through study of data relating to collisions collected by IMO. This showed a pattern in accidents which could be used in improving the design of ships: most damage, for example, is sustained in the forward part of ships and it seemed logical, therefore, to improve the standard of subdivision there rather than towards the stem. Because it is based on statistical evidence as to what actually happens when ships collide, the probabilistic concept provides a far more realistic scenario than the earlier "deterministic" method, whose principles regarding the subdivision of passenger ships are theoretical rather than practical in concept.

5. The May 1991 amendments

The amendments, which entered into force on 1 January 1994, are mostly concerned with cargo safety, and involve a complete re-writing of chapter VI. As previously noted the amendments were being prepared before the Herald of Free Enterprise disaster. The new chapter refers to the Code of Safe Practice for Cargo Stowage and Securing, the aim of which is to provide an international standard for the safe stowage and securing of cargoes.

It gives advice on ways of securing and stowing cargoes and gives specific guidance on cargoes which are known to create difficulties or hazards. It also gives advice on actions to be taken in heavy seas and to remedy cargo shift.

The Code is divided into seven chapters and a number of annexes dealing with such "problem" cargoes as wheel-based cargoes and unit loads, both of which are carried on ro-ro ships.

Other amendments concern chapter II-2: construction - fire protection, fire detection and fire extinction. Two of them apply to all ships. They affect regulations 20 and 21, which deal respectively with fire control plans and ready availability of fire-extinguishing appliances.

The remaining amendments concern new passenger ships built on or after 1 January 1994 and are particularly concerned with fire safety on ships on which large open spaces such as atriums are commonly provided.

Atriums are defined as public spaces which span three or more decks and contain combustibles such as furniture and enclosed spaces, such as shops, offices and restaurants. Regulation 28 has been revised to make it mandatory for such spaces to be provided with two means of escape, one of which gives direct access to an enclosed vertical means of escape.

Regulation 32 requires that such spaces be fitted with a smoke extraction system, which can be activated manually as well as by a smoke detection system, which is required under the amended regulation 40. Regulation 36 has been amended to make it mandatory for such spaces to be fitted with automatic sprinkler systems

6. The April 1992 Amendments

Although the entry into force of the October 1988 amendments to SOLAS meant that all ro-ro passenger ferries built since April 1990 had been built to improved damage stability standards , some Governments were still concerned at the safety levels of existing ships.

The United Kingdom proposed that the SOLAS 90 standard be made mandatory on existing ships under a phase-in programme that would have lasted from 1994 to 2004, with the ships that were furthest from the standard being converted first. The British Government pointed out that the study initiated following the Herald disaster had shown that for existing ships "capsize may still be a possibility if damage of the prescribed extent is received in the most vulnerable regions of the ship whilst operating in a moderate sea."

Although there was general agreement that an improvement to the standard for existing ships was needed, the majority of IMO Member States felt that the SOLAS 90 standard was too high. Traditionally major changes to ship design had only be made applicable to new ships because of the costs involved in applying them to existing tonnage. The industry pointed out that United Kingdom estimates showed that it would cost on average £650,000 a ship to bring the British passenger ro-ro fleet up to the SOLAS 90 standard and several Governments also raised the question of cost (they would reach a "prohibitive magnitude" according to one paper submitted to IMO).

When the proposed amendments were discussed in April 1992, therefore, the majority of Governments (with the exception of the United Kingdom and Ireland) opted for a slightly modified version of the SOLAS 90 standard and agreed that it would be phased in over 11 years beginning on 1 October 1994.

The phase-in period allowed depends upon the value of a ratio known as A/Amax, determined in accordance with a calculation procedure developed by the MSC to assess the survivability characteristics of existing ro-ro passenger ships. A/Amax is a simplified probabilistic approach attempting to assess the survivability standard of one ferry against another. It assumes a number of simplifications and is a rough guide used because it allowed all countries to carry out relatively quick calculations on a representative number of ferries. It is not a survivability standard as such but enables a hierarchy of vessels to be established.

The date by which each vessel must comply with the April 1992 standard depends on the A/Amax value attained. Those with an A/Amax value of less than 70% for example, had to comply with the amendments by 1 October 1994, the date on which the amendments entered into force.

The complete phase-in period and degree of compliance is shown below:

Compliance	
A/A max value	**Date**
Less than 70%	1 October 1994
70%-less than 75%	1 October 1996
75%- less than 85%	1 October 1998
85%- less than 90%	1 October 2000
90%- less than 95%	1 October 2005

The application of the modified SOLAS 90 standard to existing ships means modifying a large part of the world's ro-ro fleet. In some cases the changes could be extensive and the high cost involved has already led to some of them being scrapped and replaced with new tonnage.

The United Kingdom announced after the meeting that it would be considering national action to ensure the safety of ferries operating between its ports and the Continent of Europe and in 1993 an agreement was concluded which meant that existing ferries operating on most of these routes would have to meet the full SOLAS 1990 standard.

Important amendments were also made to chapter II-2 which were influenced by an accident that occurred in 1988 when the passenger ferry Scandinavian Star caught fire during a voyage from Norway to Denmark. As a result 165 people lost their lives and although the fact that the ship was a ro-ro did not contribute to the disaster it again resulted in increased public concern about this type of ship. IMO was called upon to take action and developed a number of amendments to chapter II-2 of SOLAS which were also adopted in April 1992 and also apply to existing ships.

Since 1 October, 1994, for example, all passenger ships carrying more than 36 passengers have had to be provided with plans and booklets on fire protection, fire patrol members have had to be provided with two-way portable radiotelephones and further requirements have been introduced concerning water fog applicators, portable foam applicators and hose nozzles.

From 1 October 1997 all accommodation and services spaces, stairway enclosures and corridors must be equipped with a smoke detection and alarm system as well as a sprinkler system. Other requirements concern public address and emergency alarm systems and emergency lighting.

From 1 October 2000 all stairways in accommodation and services areas must be made of steel and certain machinery spaces must be fitted with a fixed fire-extinguishing system. Requirements have been introduced regarding ventilation ducts and fire doors.

It is, perhaps, worth stressing that the April 1992 amendments are particularly important because they apply to existing ships. In the past, major changes to SOLAS have been restricted to new ships by the so-called "grandfather clauses". On this occasion the MSC decided that the new stability and fire safety standards were so important that they should be applied to existing ships as well.

1. The December 1992 Amendments

The amendments are concerned primarily with fire safety standards for new passenger ships (including of course ro-ro passenger ships) built on or after 1 October 1994, the date on which the amendments will enter into force under the Convention's "tacit acceptance" provisions.

Major changes have been made to the requirements of chapter II-2 dealing with the fire protection of new passenger ships. Several regulations are affected, dealing with such matters as fire pump sizing, the release mechanism of carbon dioxide fire-extinguishing systems, the prohibition of new halon systems, and fixed fire-detection and fire-alarm systems.

A new regulation 20-4 has been added making it mandatory for ships carrying more than 36 passengers to have plans providing information on fire safety measures. These are to be based on guidelines developed by IMO. Regulations dealing with the fire integrity of bulkheads and decks have been amended. Regulation 28 (means of escape) has been considerably altered: corridors from which there is only one route of escape will be prohibited on new ships. All means of escape must be marked by lighting or photoluminescent strip indicators placed not more than 0.3 m above the deck. The lighting must identify escape routes and escape exits.

Requirements for fire doors (regulation 30) have been improved and passenger ships carrying more than 36 passengers will have to be equipped with an automatic sprinkler, fire-detection and fire-alarm system.

The amendments will make it mandatory for new passenger ships carrying more than 36 passengers to be fitted with fire-detection alarms centralized in a control station which must be continuously manned and from which it is possible to control the fire-detection system, fire doors, watertight doors, ventilation fans, alarms, communications system and the microphone to the public address system.

2. The May 1994 amendments: the SOLAS conference

The SOLAS Convention is now so widely accepted that, to some extent at least, virtually every ship in the world complies with it. Thanks to the tacit acceptance amendment procedure it has proved possible to keep the Convention up to date and further changes were made in May 1994. Some of them were adopted by the Maritime Safety Committee expanded to include all Contracting Parties to the Convention but, for technical reasons, others were dealt with by a special conference.

The chan Chapter IX: Management for the Safe Operation of Ships: the main purpose of the new chapter is to make the International Safety Management (ISM) Code mandatory. The ISM Code was adopted by the 1993 Assembly as resolution A.741(18). This already gives it considerable force, since it was adopted unanimously and can therefore be regarded as having the full support of IMO's 152 Member States - but it is still only a recommendation. By adding the Code to SOLAS it is intended to provide an international standard for the safe management of ships and for pollution prevention. ges made by the conference included the addition of three new chapters to the Convention which are relevant to ro-ro operations.

The details are as follows:

Chapter IX: Management for the Safe Operation of Ships: the main purpose of the new chapter is to make the International Safety Management (ISM) Code mandatory. The ISM Code was adopted by the 1993 Assembly as resolution A.741(18). This already gives it considerable force, since it was adopted unanimously and can therefore be regarded as having the full support of IMO's 152 Member States - but it is still only a recommendation. By adding the Code to SOLAS it is intended to provide an international standard for the safe management of ships and for pollution prevention.

The Code requires a safety management system (SMS) to be established by the shipowner or manager to ensure compliance with all mandatory regulations and that codes, guidelines and standards recommended by IMO and others are taken into account.

Companies are required to prepare plans and instructions for key shipboard operations and to make preparations for dealing with any emergencies which might arise. The importance of maintenance is stressed and companies are required to ensure that regular inspections are held and corrective measures taken where necessary.

The procedures required by the Code should be documented and compiled in a Safety Management Manual, a copy of which should be kept on board. Regular checks and audits should be held by the company to ensure that the SMS is being complied with and the system itself should be reviewed periodically to evaluate its efficiency

The chapter is expected to enter into force under tacit acceptance on 1 July 1998. It will apply to passenger ships, oil and chemical tankers, bulk carriers, gas carriers and cargo high speed craft of 500 gross tonnage and above not later than that date and to other cargo ships and mobile offshore drilling units of 500 gross tonnage and above not later than 1 July 2002.

Chapter XI Special Measures to Enhance Maritime Safety. The chapter will enter into force on 1 January 1996. It contains four regulations, three of which are relevant to ro-ro ships.

Regulation 1 states that organizations entrusted by Administrations with the responsibility for carrying out surveys and inspections shall comply with the guidelines adopted by the IMO Assembly by resolution A.739 (18) in November 1993.

Such organizations - which include classification societies - are often used to carry out surveys and inspections required by SOLAS and other Conventions. The guidelines are intended to ensure that organizations employed in this comply with standards listed in an appendix.

Regulation 3 provides that all passenger ships of 100 gross tonnage and above and all cargo ships of 300 gross tonnage and above shall be provided with an identification number conforming to the IMO ship identification number scheme, as adopted by resolution A.600(15) in 1987. This is to enable ships to be identified no matter how many times their name or flag is changed.

Regulation 4 makes it possible for port State control officers inspecting foreign ships to check operational requirements "when there are clear grounds for believing that the master or crew are not familiar with essential shipboard procedures relating to the safety of ships."

The way in which this should be done is described in resolution A.742(18), which was adopted by the IMO Assembly in November 1993. It acknowledges the need for port States to be able to monitor not only the way in which foreign ships comply with IMO standards but also to be able to assess "the ability of ships' crews in respect of operational requirements relevant to their duties, especially with regard to passenger ships and ships which may present a special hazard".

Several other amendments will enter into force on 1 January 1996. They include a new regulation 8-1 in chapter V which makes it possible to introduce mandatory ship reporting systems. By making IMO-adopted ship reporting systems mandatory, the SOLAS amendments make it obligatory for ships entering or using a system to give their position, identity and other information. This will enable their journey through the system to be tracked. If the ship begins to head off course, or if there is a danger of collision or grounding, the shore authority will be able to give a warning and take what other action is necessary to prevent an accident.

3.3 The Estonia disaster of September 1994

Following the adoption of the May 1994 amendments to SOLAS, the shipping community was looking forward to a period of consolidation during which the changes of the previous few years could be absorbed. It appeared to many that the doubts concerning ro-ro ships had been solved and that no more major changes were needed. Then, on 28 September 1994 the passenger ro-ro ship Estonia suddenly capsized in a severe storm in the north Baltic Sea and sank with the loss of more than 900 lives.

The scale of the disaster was so great that immediately the whole question of ro-ro safety was reopened. Preliminary inquiries showed that the outer bow door of the ship had been ripped off during the storm, allowing water to accumulate on the car deck to such an extent that the ship very quickly listed and then rolled over and sank. The accident occurred in the early morning when most passengers were asleep and the ship sank so suddenly that the majority of them had virtually no chance of escaping. And unlike the Herald of Free Enterprise and the European Gateway the Estonia was operating in deep water and did not end up lying on her side on a sandbank but sank to the bottom several hundred metres below.

The fact that the accident once again involved a bow door and water on the car deck led to renewed criticisms of ro-ros, the way they were operated and the basic ro-ro concept.

On 4 October, the Secretary-General of IMO, Mr William A. O'Neil, proposed that a complete review of the safety of roll-on/roll-off ferries be carried out by a specially selected panel of experts. The Secretary-General announced this initiative after consultation with Dr Giuliano Pattofatto, the chairman of the MSC.

He made it clear that the review should look not only at such key issues as bow and stern door safety and the possible need for sub-divisions on the vehicle deck but everything involved in ro-ro ferry operations. He said: "During the last few years a great deal has been done to improve the safety of ferries. Nevertheless, we cannot simply refer to what has been done during the last few years and claim that there is no need for further action. The only way of reassuring people that ro-ro ferries are safe is by looking at every aspect of ro-ro ferry operations and ensuring that any problems are remedied."

In his proposals, which were submitted to the MSC for consideration at its meeting in December 1994, the Secretary-General listed a number of items which needed particular attention. They included:

- the strength and watertightness of openings to the vehicle spaces, in particular bow and stern doors

- increasing the survivability standards by the fitting of bulkheads

- the evaluation of life-saving appliances and on-board evacuation arrangements, if necessary

- the need to prepare operational guidelines for use in adverse weather conditions, given the size and type of the ro-ro ships concerned and their area of operation

- the on-board communication issues, in particular when ships are manned by multinational crews carrying multinational passengers

- revising the reporting of incidents concerning safety matters of ro-ro ships to appropriate authorities and the action the authorities should take on receiving these reports.

The MSC met from 5-9 December and agreed to establish a panel of experts to carry out an intensive study into ro-ro design and operations. It would work under the supervision of a Steering Committee chaired by Dr Pattofatto. Mr Torkild Funder of Denmark, a former chairman of the MSC, was chosen to be chairman of the panel of experts, which was to consist of designated specialists and the chairmen of a number of IMO sub-committees.

1. The MSC's 65th session

The panel's reports and recommendations were considered by the Steering Committee in April and then by the full MSC at its 65th session in May. The report represented the most complete study into ro-ro ferry safety ever made and it is expected that its implications will be far reaching and take several years to implement fully.

The recommendations of the Panel of Experts focused on requirements applicable to the existing ro-ro passenger fleet. However, due to the nature of the recommendations, in some cases the proposed requirements have been extended to passenger ships other than ro-ro ferries.

All appointed experts were made available by Member Governments or interested segments of the industry on condition that their participation in the Panel would incur no financial obligations to the Organization.

The Panel was instructed by the Steering Committee to also take into account in its work accidents with a low probability, the consequences of which would, however, be deemed unacceptable. This instruction, seen against the background of the short time available, made it impossible for the Panel to draw the cost-benefit analysis which should, otherwise, accompany any proposals for amendments to mandatory instruments.

The Panel was aware that some of its proposals would have severe implications to existing ro-ro passenger ships and might even lead to some ships being forced out of service. But it considered it necessary to present a complete package of proposals so that the industry could be ensured that, for a number of years, additional requirements, if deemed necessary, would only address issues entailing minor financial implications.

It is therefore not surprising that, even against the background of the accidents which led to the establishment of the Panel, it was never suggested that the ro-ro concept should be discontinued, nor would this, from a practical point of view, be possible. The Panel saw its main task as being to propose such changes to the construction, equipment and operation of ro-ro ships as would improve their safety and restore public faith in the transportation of passengers and goods by this form of transport.

Although it was recognized that implementing the complete package of proposals would involve several years of work, the MSC recognized that some matters had to be dealt with as a matter of urgency. It was therefore agreed that a special conference would be held at IMO headquarters in November 1995 to consider a number of proposed amendments to SOLAS. These included amendments concerning the crucial question of stability.

2. Intact and damage stability of Ro-Ro passanger ships

One of the most important proposals in the report of the Panel of Experts concerns the effect of a build-up of water on the enclosed ro-ro deck, which it describes as the "most dangerous problem for a ro-ro ship."

As we have seen, since April 1990 all new passenger ro-ro ships have had to be built according to SOLAS 90 while a slightly modified version was made applicable to existing ro-ro passenger ships. Tests carried out in the United Kingdom have shown that SOLAS 90 would give an "adequate standard" of protection following an accident, such as a collision, which occurs in wave heights of up to 1.5 metres.

The Panel concluded that these requirements should be improved to include the effect of water being accumulated on the ro-ro deck in order to enable the ship to survive in more severe sea states. It felt that this could certainly not be excluded when realistic scenarios are considered and the Committee endorsed that view.

It agreed the Panel's proposals would have profound implications for the existing ro-ro fleet, necessitating substantial design and construction improvements which would, in turn, be costly and could make some existing ro-ros commercially non-viable. Understandably, there were considerable difference of opinion among delegates about the proposals and in particular about the recommendation that SOLAS 90 should be modified to take into account water on the vehicle deck.

Nevertheless, draft texts were prepared and circulated to Parties to the SOLAS Convention. This had to be done at least six months before the November Conference for legal reasons. Having decided this, the Committee turned its attention to other issues raised by the Panel of Experts' report.

3. One-compartment standard ships

The Committee agreed that the one-compartment standard should not be accepted for new ro-ro passenger ships carrying more than a relatively low number of passengers. This standard means that ships should be able to survive if one watertight compartment is flooded.

The Committee agreed that existing one-compartment ships should be modified to comply with a two-compartment standard or have their certified number of passengers reduced over a period of years to an approved limited number.

4. Second line of defence

It was agreed that there should always be an inner door behind the bow door or visor to act as a second line of defence. Further measures to prevent water entering the ro-ro deck - for example, through doors leading to other parts of the ship - were agreed. These include the banning of the practice of operating ro-ro passenger ships with watertight doors open. This would only be allowed if such doors are power-operated and controlled from the bridge.

5. Drainage

It was agreed that the drainage of water from the ro-ro deck should be improved. An amendment to SOLAS requiring that discharge valves, which can be closed from a position above the bulkhead deck, shall be kept open at sea was submitted to the Conference.

6. Operational matters

There was agreement that ferry operations are generally performed in a safe and orderly manner, but experience has shown that some improvements could be made.

The MSC also recognized that early implementation of the International Safety Management (ISM) Code will have an important impact on the safety of ro-ro passenger ships. Although it will not be applied to passenger ships until 1 July 1998, the MSC agreed that this does not prevent Governments from making the Code mandatory for ships flying their flags at an earlier date and a recommendation that this be done was actually adopted by IMO in 1993.

7. Working language

The MSC stressed the importance of all crew members being able to understand each other. It agreed to an amendment to SOLAS requiring that a working language be established for each individual roro passenger ship and further agreed that this requirement could be extended to all passenger ships.

8. Operational limitations

In some cases limitations are imposed on how and where a ship may be operated, but these can be lost or mislaid during the ship's life, for example, if it changes hands or flag. The MSC approved a new SOLAS regulation making it a requirement for this information to be included in a manual to be kept by the master which would remain with the ship for its entire life and be updated as necessary and that this requirement be made applicable to all types of ships.

9. Lashing and securing of cargoes

On 1 July 1996 a SOLAS amendment will enter into force making it mandatory for ships to carry a Cargo Securing Manual. The rapid turn-round times of ro-ro ships makes the lashing and securing of cargoes difficult and the MSC agreed to an amendment to SOLAS to ensure that securing in compliance with the Code be completed before ro-ro ships are allowed to sail. It points out the importance of ensuring that cargoes are properly stowed and secured within containers and wheeled vehicles carried on ro-ro ships. It also undertook to arrange appropriate solutions to this problem with bodies dealing with road transport.

10. Access to ro-ro decks

The MSC agreed that access by passengers to the ro-ro deck when the ship is under way should be banned

11. Alarms on, and surveillance of, hull doors

The Committee decided that a better safety level could be achieved if alarms required on the navigating bridge were supplemented by an audible alarm indicating any change of state of the doors under surveillance. Audible alarms should be fitted to doors for which surveillance is required. Leakage surveillance by closed circuit television should be provided in the engine room as well as on the bridge.

12. Constructional matters

An amendment to SOLAS designed to eliminate the risk of flooding of vehicle spaces through ventilation trunks and air pipes was approved.

13. Training and related matters

As draft amendments to the STCW Convention and a related STCW Code were to be adopted at a conference in June/July this year, the MSC felt that there was a need for additional training of crew members with special duties in emergencies, such as crews of fast rescue boats

It further agreed that there should be additional training for personnel on ro-ro passenger ships in such topics as shore-based fire fighting, crowd management, loading and unloading, stability, crisis management and human behaviour.

14. Communications

The MSC agreed to develop performance standards for public address systems and that requirements should be introduced into SOLAS to ensure that they operate efficiently. To ensure efficient external communications, arrangements should be made so that at least one member of the crew is dedicated to perform radiocommunication duties in the event of an emergency.

The MSC agreed to ensure that distress messages are efficiently sent and received and that the work currently being carried out by IMO concerning the mandatory carriage of identification transponders be given high priority.

The MSC further agreed that float-free voyage data recorders - similar to the "black boxes" carried by aircraft - should be fitted to ro-ro passenger ships

15. Survey requirements

The MSC agreed that unscheduled inspections, especially concentrated on operational matters, should be held at least once a year on ro-ro passenger ships. As this will require an amendment to SOLAS that will take time to bring into force, an Assembly resolution calling for Governments to take action to ensure that damage to shell doors is reported so that remedial action can be taken on similar ships was approved for adoption as an interim solution

16. Search and rescue

The MSC noted that maritime search and rescue (SAR) aircraft are not always equipped with equipment covering maritime radio frequencies. The matter is still under discussion with the International Civil Aviation Organization (ICAO) but so far with no positive results. The MSC agreed that the situation which may result in ships and SAR aircraft being unable to communicate in connection with SAR operations must be seen as unacceptable. It proposed that this be remedied by adopting an amendment to the SOLAS Convention which would require ships to be equipped so that they can communicate with SAR aircraft.

An amendment to SOLAS was approved requiring ferry operators to establish the number and identities of passengers. Other amendments were prepared that will require ro-ro passenger ships to carry an approved SAR plan that can be put into effect in the event of an emergency.

Although it did not regard the creation of helicopter landing areas as practical for most ferries, the MSC agreed that requirements on the establishment of a helicopter pick-up or hoisting area on board existing ships should be adopted by the Conference.

Changes were proposed to the SAR Convention, including the addition of operational guidance for distress and SAR communications.

17. Fire safety

The MSC recalled that although a number of changes to the existing fire safety regulations have been introduced into SOLAS, the threat of a local fire starting in a high-risk area is not adequately addressed. It therefore agreed to an amendment that would require the installation of a local fireextinguishing system in such areas.

18. Life-saving appliances

The MSC recognized that, in the case of a rapid capsize - the greatest danger facing ro-ro ships - there is no possibility of an organized abandonment of the ship under a trained crew. Normal lifesaving appliances (LSAs) and practices therefore appear insufficient and it therefore recommended that LSAs for ro-ro ships must be designed so that they can be used by anyone with little or no training. It agreed to a series of proposals based on this principle.

SOLAS regulations require survival craft to be embarked and launched within 30 minutes of the order being given to abandon ship. This is only a type approval and design criterion which should not be taken as an indication that ships will stay afloat for at least 30 minutes, irrespective of the damage they have sustained. Such an indication would be impossible because it is impossible to specify how much damage will result from an accident.

The proposed requirements concern liferafts, the provision of fast rescue boats on ferries, rescue platforms and improvements, such as the fitting of lights to lifejackets. The Committee agreed the addition of other long-term measures to its work programme for further consideration.

19. Evacuation arrangements

The MSC agreed to a number of changes to the arrangements for evacuating ships in the event of an emergency. These are designed to ensure that evacuation routes are arranged to allow the rapid and orderly movement of passengers to assembly stations, embarkation stations and survival craft.

It agreed to further develop an active system for guidance of passengers in cases of emergency and take other measures to improve evacuation procedures. This includes reviewing the standard signs and symbols displayed on ships in line with the standards of the International Organization for Standardization (ISO). A study to ascertain the time taken to evacuate ro-ro passenger ships was also agreed. The matter will be further discussed at the intersession at working group.

20. Information to passengers

Recognizing that the level of information required by passengers may vary from country to country and that it would be impossible to make detailed requirements, the MSC approved guidelines for passenger safety instructions on ro-ro passenger ships which should also be made applicable to all passenger ships.

21. Crisis management

The MSC considered measures for improving the basis for rapid decision-making in emergencies which could be assisted by introducing a fully computerized monitoring and decision support system to alert the officer of the watch if a critical trend is detected or the alarm level is exceeded. A recommendation was agreed on this subject in respect of new ships while an amendment to the SOLAS Convention was approved to apply to existing ro-ro passenger ships. The MSC recognized though that more experience is needed before such a system can be made mandatory.

A resolution concerning training in crisis management and human behaviour for personnel on board ro-ro passenger ships was adopted in July 1995 by the conference of Parties to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 1978.

22. Formal safety assessment

Recognizing that FSA is used in other areas - for example, the offshore industry - as a way of identifying hazards and then deciding on how best they should be managed, the MSC agreed to give priority to considering adopting Formal Safety Assessment (FSA) as a basis for IMO's future work. It further recognized that the outcome of this work should not only result in regulations to be applied at the ship design and operation stages but that FSA should also form part of the overall rule-making process of the Organization.

The MSC agreed that technical requirements alone, both constructional and operational, will not establish a safe environment in the area of passenger ships. It is, therefore, necessary that every person with a professional interest in passenger ships feels responsible for their safety.

Changes already made or in the course of being made will help but the MSC stressed that "establishing a safety centred culture cannot...be established by regulations." A resolution adopted by IMO Assembly in November refers to this

The November 1995 SOLAS conference

The conference had on its agenda a number of important - and controversial - proposed changes to SOLAS. The most important concerned requirements for the watertight integrity and stability of roro passenger ships.

A major success was the unanimous adoption of amendments which will have the effect of applying the full SOLAS 90 damage stability standard to existing passenger ro-ro ferries. A new regulation chapter II-1, 8-1 will mean that existing ro-ro passenger ships will have to fully comply with SOLAS 90 in accordance with an agreed phase-in programme, which will depend on how closely a ship complies with the A/Amax ratio. This is determined in accordance with a calculation procedure designed to assess the survivability characteristics of existing ro-ro passenger ships. Ships which only meet an A/Amax value of 85%, will have to comply fully by 1 October 1998 and those meeting 97.5% or above by 1 October 2005.

CHAPTER 4

(FINAL THOUGHTS)

In conclusion After the two disasters mentioned above a lot of changes were made by the MSC's 65th session in order to improve the safety, avoid future disasters and ensure that, the cargo and most importantly the lives of the passangers and crew are of the utmost importance.

As history has shown there have been a many accidents despite all the changes and additions to the safety and security of the vessels, but you cant always avoid or predict nature and there will always be the factor of human error despite all the training and navigational assistance.

On the bright side of things only 3 accidents have happened since 2015 without any casualties and improvements are being made constantly to increase the safety standards of all vessels.

Finally we hope that after reading our thesis, we have piqued the interest of our colleagues and more current and future officers will seek employment in these types of vessels.

BIBLIOGRAPHY

https://en.wikipedia.org/wiki/Roll-on/roll-off

https://www.marineinsight.com/types-of-ships/what-are-ro-ro-ships/

https://www.marineinsight.com/naval-architecture/ro-ro-ship-design-dangers/

https://worldmaritimenews.com/archives/250728/worlds-largest-short-sea-ro-ro-vessel-named-in-dublin/

http://www.largestshipintheworld.com/largest_ships_in_the_world/worlds-largest-roro-vessel-launched.php

http://www.imo.org/en/OurWork/Safety/Regulations/Documents/RORO.pdf

ttps://www.wartsila.com/docs/default-source/product-files/sd/merchant/white-paper-o-ship-design-2014-merchant-lng-roro-vessel.pdf?sfvrsn=4

https://conro.crowley.com/ships